MATERNAL DEATHS BEFORE AND DURING COVID-19 PANDEMIC: CAUSES AND AVOIDABLE FACTORS IN A TERTIARY HOSPITAL IN SOUTH AFRICA

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Medicine in Obstetrics and Gynaecology

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DECLARATION

I, Ongombe Lunda, hereby declare that this dissertation report is of my own unaided work. I am submitting this research report for the degree Master of Medicine (in the submissible format with my protocol and extended literature review) in the branch of Obstetrics and Gynaecology at the University of the Witwatersrand, Johannesburg. This research report has not been submitted before for any degree or examination at this or any other university.

(Signature of candidate)

09th July 2025

Abstract

Aim: To determine the institutional maternal mortality ratio (iMMR) and avoidable factors (AVFs) before and during the COVID-19 pandemic (COVID-19-P) in a tertiary hospital in South Africa.

Methods: This was a retrospective cross-sectional study. We reviewed medical records to compare iMMR and associated AVFs two years before (March 2018 - February 2020) and two years during (March 2020 - February 2022) COVID-19-P.

Results: Fifty-eight maternal deaths (MDs) were recorded but available data was for 57 (35 before and 22 during COVID-19-P). The highest iMMR per 100,000 live births over a 12-month period was 329.1 before and 201.8 during COVID-19-P. The mean ages were 31.0 ± 6.9 and 31 ± 6.2 years, p=0.822 before and during COVID-19-P, respectively. During COVID-19-P, 40.9% (9/22) were diagnosed with COVID-19. Before and during the pandemic, 71.4% (25/35) and 68.2% (15/22) p=1.0 were admitted into an intensive care unit (ICU), respectively, with corresponding 71.4% (25/35) and 50% (11/22), p=0.026 requiring mechanical ventilation. There was a significant difference in the primary causes of death (p=0.009) for the two periods, with preeclampsia with severe features (22.9%, 8/35) being the leading cause before COVID- 19-P compared to COVID-19 (31.8%, 7/22) during the pandemic. AVFs related to healthcare professionals were the most common occurring in 22/35 and 12/22 of the women who died before and during COVID-19-P, respectively. Before COVID-19-P, the most frequent patient-, healthcare professional-, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care bed spaces. During COVID-19-P, the most common patient-, healthcare worker- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability of ICU/high care spaces.

Conclusion: iMMR was lower during than before COVID-19-P. AVFs related to healthcare professionals were the most common.

Keywords: Avoidable factor, COVID-19, maternal deaths, maternal mortality ratio, Severe Acute Respiratory Syndrome Coronavirus 2

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ABBREVIATIONS

ART	Antiretroviral Therapy
COVID-19	Coronavirus Disease 2019
COVID-19-P	Coronavirus Disease 2019 Pandemic
CHCs	Community Health Clinics
DH	District Hospital
HDP	Hypertensive Disorder of Pregnancy
HIV	Human Immunodeficiency Virus
ICU	Intensive Care Unit
Immr	Institutional Maternal Mortality Ratio
K/T	Klerksdorp/Tshepong
MD	Maternal Death
MMR	Maternal Mortality Ratio
OR	Odds Ratio
PPH	Postpartum hemorrhage
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus-2
TB	Tuberculosis
WHO	World Health Organization

JOURNAL ARTICLE (Formatted for PLOS ONE)

Title: Maternal deaths before and during COVID-19 pandemic: Causes and avoidable factors in a tertiary hospital in South Africa, 2018–2022

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Ghada Daef: conceptualization, investigation, methodology, supervision, validation, writing – review and editing

Gbenga Olorunfemi: formal analysis, methodology, validation, writing – review and editing

Nnabuike Chibuoke Ngene: conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, writing – review and editing

Abstract

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1. Introduction

The socioeconomic challenges and adverse health outcomes associated with the coronavirus disease 2019 (COVID-19) pandemic have been devastating to many individuals, families, and communities. However, evidence-based interventions such as vaccination and non-pharmacological interventions including regular hand washing, as well as attainment of herd immunity, have largely halted the scourge of the disease. COVID-19 was first reported in China in the city of Wuhan on 8 December 2019 [1]. It is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). On 11 March 2020, the World Health Organization (WHO) declared the disease a pandemic [1]. The disease is highly infectious and in Sub-Saharan Africa had a case fatality rate of 3.4% [2]. As of 23 December 2024, it had resulted in 7.1 million deaths worldwide [3]. In South Africa, the first case was reported in the KwaZulu-Natal province on 6 March 2020. The infection rapidly spread to other provinces with the national cumulative confirmed cases per million people increasing to 3 398.46 in six months (as of 8 September 2020) and to 58 068.32 in two years (as of 6 February 2022). By 6 June 2022, the figure had become 63 596.97 per million people and the gradient plateaued [4]. To place this in context, South Africa had a mid-year population of approximately 60 million in 2021 [5]. By 20 June 2022, all the COVID-19 restrictions in South Africa had been lifted [6]. Following a declining trend in the number of deaths and hospitalizations from the disease globally, WHO declared on 5 May 2023 that COVID-19 was no longer a public health emergency of international concern [7]. Some survivors of the disease, however, are still battling to cope with

the debilitating effects of long COVID-19. The pandemic disrupted activities of daily living including the usual routines in the health sector and, as a result, healthcare resources had to be redistributed to contain the pandemic [8]. Furthermore, COVID-19 deaths preferentially affected vulnerable groups such as persons with comorbidity (including hypertension and diabetes) and those with immunosuppression [9]. Consequentially, many maternal deaths (MDs) due to COVID-19 occurred globally including in South Africa [10].

During the pandemic, pregnant women in South Africa with severe COVID-19 were transferred to regional and tertiary hospitals for further management because of the availability of established critical care services at these referral centers. In the context of this referral pattern, the contribution of COVID-19 to MDs in South Africa has not been exhaustively studied. Although data on institutional MDs in South Africa are collated and published every three years in the Saving Mothers Report [10], evidence suggests that the most common causes of and trends in MDs at the national level (based on the consolidated data from various healthcare facilities) may be different from a hospital-specific data review [11]. The 2017–2019 Saving Mothers Report suggests that the national institutional maternal mortality (iMMR) ratio increased during the first wave of the COVID-19 pandemic (COVID-19-P) in South Africa, from 98.8 to 126.1 per 100,000 live births [10]. Whether or not iMMR increased in each maternity unit in South Africa during the COVID-19-P remains uncertain.

The iMMR, causes of MDs, and associated avoidable factors (AVFs) before and during COVID-19-P have not been studied in Klerksdorp/Tshepong (K/T) Hospital, the only tertiary hospital in the North West province of South Africa. The information gained from such research could assist with the identification and implementation of interventions to prevent future MDs and prepare the health system for future pandemics. The aim of this study,

therefore, was to determine the trends in iMMR, causes, and AVFs associated with MDs in a tertiary hospital in the North West province in South Africa over a four-year period (1 March 2018–28 February 2022) comprising two years before and two years during the COVID-19 pandemic.

2. Materials and Methods

2.1 Study design and period

This is a four-year retrospective cross-sectional record review of all in-hospital MDs that occurred before COVID-19-P (1 March 2018–28 February 2020), and during it (1 March 2020–28 February 2022). The study covered the 24-month period immediately before COVID-19 was diagnosed in South Africa in March 2020 and the immediate 24-month period during the COVID-19-P. Data collection from the medical records for research purposes was from 1 June 2022 to 31 December 2022.

2.2 Study setting

The study was conducted in the K/T hospital, which is made up of two healthcare facilities namely Klerksdorp Hospital in Klerksdorp town and Tshepong Hospital in Jouberton township) in Kenneth Kaunda District, North West Province, South Africa. The two public hospitals are tertiary facilities that function as a complex. The Department of Obstetrics and Gynecology is in Klerksdorp Hospital and conducts 480 deliveries per month. It receives referrals from the district and provincial hospitals as well as 16 primary healthcare clinics in the Kenneth Kaunda Health District and other health districts in the North West province. Four of the primary health care clinics function as midwife-led obstetric Units. Of note, the referral patterns to the hospital did not change during the study period, with all patients presenting with

respiratory symptoms suspected to be tuberculosis and those diagnosed with COVID-19 being screened for tuberculosis.

In South Africa, the initial three COVID-19 waves (high rate of SARS-CoV-2 transmission) occurred from April 2020 to September 2021 with the timing of the surges being similar across the provinces in South Africa [12, 13]. There was successive higher positivity of diagnostic test, incidence, and mortality of COVID-19 across the three periods with the ancestral strain, Beta (B.1.351) and Delta (B.1.617.2) variants being responsible for the first, second, and third waves, respectively [12]. From October 2021 to February/March 2022, another wave caused by Omicron (BA.1) occurred although less positivity and mortality were recorded [14]. Following this period, the disease became stable as vaccination and natural infection achieved herd immunity.

2.3 Study population and sample

The study population was MDs in the study setting. The study sample comprised all women who died in the K/T hospital complex that met the definition of MD during the 4-year study period. This was the eligibility criteria. According to the WHO, maternal mortality is the demise of any woman during the period of pregnancy (irrespective of the weeks of gestational age and location of the pregnancy) or within 42 days following childbirth as a result of causes related to or exaggerated by pregnancy but excluding accidental causes [15].

2.4 Data collection

The admission and discharge ward registers in the Obstetrics and Gynecology Department in the K/T hospital complex together with the departmental list of MDs were used to identify the MDs and childbirths that occurred in the hospital during the four-year period under review.

The files of the listed deceased women were retrieved from the records department of the hospital, and the data collection and review of the clinical records were performed by the principal investigator. Afterwards, the research supervisors discussed the MDs with the principal investigator during plenary meetings. Fig 1 is a flow diagram illustrating the data collection processes and the type of data collected.

Fig 1. Flow diagram on data collection

2.5 Data analysis

Data was analyzed using SPSS version 29 (IBM, Armonk, NY, USA), with Joinpoint Regression Program, version 5.0.2 (National Cancer Institute https://surveillance.cancer.gov/joinpoint/) being used to evaluate the six-monthly percentage change in iMMR. A normality check was performed on numerical data using the skewness-Kurtosis test and visual assessment of the distribution of data in plots and charts including the normal curve on a histogram. Categorical variables were presented as frequencies and percentages. Numerical variables were summarized as mean with standard deviation (for normally distributed data) and median with interquartile range (for skewed data). Descriptive statistics was used to compute the trend in MDs, live births, and iMMR. The iMMR was calculated by dividing the number of MDs during a specified period by the total live births during the same period, multiplied by 100 000. A line graph showing six and 12-monthly trends in iMMR was plotted. The six-monthly point periods show the trend in iMMR and provide eight data points, which exceeds the minimum seven required for jointpoint regression analysis [16]. Numerical variables in the two periods (before and during COVID-19-P) were compared using the student t-test and Mann-Whitney U test for normally distributed data and skewed data, respectively. Categorical data were compared using Pearson's Chi-square distribution test

and the Fisher exact test, as appropriate. Statistical significance was set at $p \leq 0.05$. Missing data were excluded from the calculation of the p-value.

2.6 Ethics

Approval from the University of Witwatersrand Human Research Ethics Committee (Reference M220359) was obtained before the inception of the study. The management of the K/T hospital complex also gave approval. During data collection, the medical records of the individual participants (deceased women) had their identities which were accessible to the principal investigator. However, no information that could identify individual participants was used after data collection (including during data capturing, statistical analysis, or reporting of the study findings).

3. Results

There were 58 MDs during the study period, but the medical record of one woman who demised during COVID-19-P could not be found. She was excluded from the analysis but included in the mortality trends.

3.1 Sociodemographic characteristics

There was no statistical difference between the two study periods in terms of the socio-demographic characteristics of the women (Table 1). All 58 reported MDs were Black African women. There was no marked difference between the mean age (in years) of the two groups: 31.0 ± 6.0 before and 31.1 ± 6.2 during COVID-19-P (p = 0.822). Two MDs occurred among teenagers in the period before COVID-19-P.

Table 1. Sociodemographic characteristics of the women

Variable	Values n (%), mean ± SD			p-value
	Before COVID-19 (March 2018 to February 2020)	During COVID-19 (March 2020 to February 2021)	Total	
Mean age ± SD (years)	31.0 ± 6.90	31.1 ± 6.20	31.0 ± 6.0	0.822[t]
Age (years), n (%)				0.344[f]
≤24	3(8.6)	5(22.7)	8(14.0)	
25 – 34	25(71.4)	12(54.5)	37(64.9)	
≥35	7(20.0)	5(22.7)	12(21.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Residence, n (%)				0.621[f]
Kenneth Kaunda (KK) District	22(62.9)	17(77.3)	39(68.4)	
Outside KK district but in same province	12(34.3)	5(22.7)	17(29.8)	
Outside the province	1(2.9)	0(0.0)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Marital status				0.652[f]
Single	32(91.4)	21(95.5)	53(93.0)	
Married	3(8.6)	1(4.5)	4(7.0)	
Total	35(100.0)	22(100.0)	57(100.0)	
Occupation				1.00[f]
Employed	2(5.7)	2(9.1)	4(7.0)	
Unemployed	33(94.3)	20(90.9)	53(93.0)	
Total	35(100.0)	22(100.0)	57(100.00)	
Race				Constant
Black	35(100.0)	22(100.0)	57(100.0)	-
Total	35(100.0)	22(100.0)	57(100.0)	
Cigarette smoking				0.134[f]
Yes	7(20)	1(4.5)	8(14.0)	
No	28(80)	21(95.5)	49(86)	
Total	35(100.0)	22(100.0)	57(100.0)	
Substance use				0.192[f]
Yes	2(5.7)	4(18.2)	6(10.5)	
No	33(94.3)	18(81.8)	51(89.5)	
Total	35(100.0)	22(100.0)	57(100.0)	
District referred from				0.363[f]
Kenneth Kaunda	24(68.6)	16(72.7)	40(70.2)	
Bojanala	0(0.0)	2(9.1)	2(3.5)	
Ngaka Modiri Molema	4(11.4)	1(4.5)	5(8.8)	
Ruth Segomotsi Mompati	6(17.1%)	3(13.6)	9(15.8)	
Kuruman in Northern Cape	1(2.9)	0(0.0)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: t, student t-test; f, Fisher exact test. The p-value applies only to the comparison between the periods before and during COVID-19)

3.2 Antenatal profile, COVID-19 status, and chronic medical conditions

Table 2 is a summary of the antenatal profile, COVID-19 status, and chronic medical condition of the women. Nearly all (94.7%) had been referred to the institution. A total of

57.9% (33/57) of the women had antenatal care (18 before and 15 during COVID-19-P, p = 0.056). The median parity of all the women was 3 (Interquartile range [IQR] 2 - 4), comprising 3 (2 - 3) before and 3 (2 - 4) during COVID-19-P, p = 0.299. At booking, 57.9% (33/57) of the women had anemia: 62.7% (22/35) before and 50.0% (11/22) during the pandemic, p = 0.476.

Table 2. Antenatal profile, COVID-19 status, and chronic medical conditions

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID-19 (March 2018 – February 2020)	During COVID-19 (March 2020 – February 2021)	Total	
Referral status at the facility				1.00[f]
Referred	33(94.3)	21(95.5)	54(94.7)	
Not referred	2(5.7)	1(4.5)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Delay in referral				1.00[f]
Yes	7(20.0)	4(18.2)	11(19.3)	
No	28(80.0)	18(81.8)	46(80.7)	
Total	35(100.0)	22(100.0)	57(100.0)	
Referring institution				0.132[f]
Clinic in Kennet Kaunda	16(45.7)	10(45.5)	26(45.6)	
Hospital in Kennet Kaunda	1(2.1)	5(22.7)	6(10.5)	
Institution outside Kennet Kaunda in North West Province	11(31.4)	6(27.3)	17(29.8)	
Institution outside North	2(5.7)	0(0.0)	2(3.5)	
Tshepong Hospital	3(8.6)	0(0.0)	3(5.3)	
Not referred	2((5.7)	1(4.5)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of chronic condition, n (%)				0.810[f]
HIV	21(60)	14(63.6)	35(61.4)	
Chronic Hypertension	1(2.9)	1(4.5)	2(3.5)	
Epilepsy	0	1(4.5)	1(1.8)	
HIV and hypertension	1(2.9)	0	1(1.8)	
No chronic condition	12(34.3)	6(27.3)	18(31.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
HIV antiretroviral therapy (ART)				1.00[f]
On ART	12(34.3)	7(31.8)	19(33.3)	
Not ART	6(17.1)	3(13.6)	9(25.7)	
HIV negative	14(24.6)	8(36.4)	22(62.8)	
Missing data among women living with HIV	3(8.6)	4(18.2)	7(12.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
CD4 count (cells/µl) range and median, n = 26				0.133[m]
Minimum	4	46	4	
Maximum	1484	1067	1484	
Median, IQR	116[11.5 – 378]	331[197 – 667]	312 [39 – 459]	

Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID-19 (March 2018 – February 2020)	During COVID-19 (March 2020 – February 2021)	Total	
CD4 Category (cells/μl)				0.319[f]
<199	9(42.9)	2(14.3)	11(31.4)	
200-499	5(23.8)	5(35.7)	10(28.6)	
≥500	3(14.3)	2(14.3)	5(14.3)	
Missing data	4(19.0)	5(35.7)	9(25.7)	
Total	21(100.0)	14(100.0)	35(100.0)	
Bactrim use if CD4 <200 cells/μl				0.616[f]
Yes	2(9.5)	0(0.00)	2(5.7)	
No	10(47.6)	7(50.0)	17(48.6)	
Unknown	1(4.8)	0(0.00)	1(2.9)	
CD4≥200	8(38.1)	7(50.0)	15(42.9)	
Total	21(100.0)	14(100.0)	35(100.0)	
HIV viral load (copies/ml), range, and median				0.285[m]
Minimum	0	0	0	
Maximum	4697585	1180739	4697585	
Median (IQR)	1787 [45–83010]	16844.5 [1458–171120.8]	4738 [60.5-106274]	
HIV viral load (copies/ml), category				0.261[m]
<200	6(28.6)	2(14.3)	8(22.9)	
≥200 – 99999	7(33.3)	4(28.6)	11(31.4)	
≥100000	2(9.5)	4(28.6)	6(17.1)	
Missing data	6(28.6)	4(28.6)	10(28.6)	
Total	21(100.0)	14(100.0)	35(100.0)	
Previous pregnancy ≥ 24 weeks' Gestation				0.141[m]
Minimum	1	1	1	
Maximum	9	6	9	
Median [IQR]	3[2-3]	3[2-4]	3[2-4]	
Previous pregnancy ≥ 24 weeks' gestation				0.299[f]
1	5(14.2)	2(9.1)	7(12.3)	
2 – 4	27(77.1)	16(72.7)	43(75.3)	
≥5	2(5.7)	4(18.1)	6(10.6)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Previous pregnancy less than 24 weeks' gestation				0.397[m]
Minimum	0	0	0	
Maximum	8	5	8	
Median [IQR]	2[1-2]	2[1-3]	2[1-3]	

Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-Value
	Before COVID-19 (March 2018 – February 2019)	During COVID-19 (March 2020 – February 2021)	Total	
Previous pregnancy less than 24 weeks' gestation				0.326[f]
0	4(11.4)	1(4.5)	5(8.8)	
1-2	23(65.7)	13(59.1)	36(63.1)	
≥3	7(20.0)	8(36.4)	15(26.3)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Previous caesarean section				0.698[f]
Yes	6(17.1)	6(27.3)	12(21.0)	
No	28(80.0)	16(72.7)	44(77.2)	
Unknown	1(2.9)	0(0.00)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Attended antenatal care clinic				0.056[f]
Yes	18(51.4)	15(68.2)	33(57.9)	
No	13(37.1)	2(9.1)	15(26.3)	
Unknown	3(8.57)	4(18.2)	7(12.3)	
Missing data	1(2.9)	1(4.5)	2(3.5)	
Total	35(100.0)	22(100.0)	57(100.0)	
Gestational age at booking				0.301[c]
Less than 20 weeks	9(25.7)	8(36.4)	17(29.8)	
Above 20 weeks	10(28.6)	8(36.4)	18(31.6)	
Unbooked	13(37.1)	4(18.2)	17(29.8)	
Unspecified	3(8.6)	2(9.1)	5(8.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Anaemia during pregnancy				0.476[c]
Yes	22(62.9)	11(50.0)	33(57.9)	
No	9(25.7)	7(31.8)	16(28.1)	
Missing data	4(11.4)	4(18.2)	8(14.0)	
Total	35(100.0)	22(100.0)	57(100.0)	
Rapid Plasma Reagin				0.098[f]
Non-reactive	21(60)	16(72.7)	37(65.0)	
Unknown	11(31.4)	2(9.1)	13(22.7)	
Missing data	3(8.6)	4(18.2)	7(12.3)	
Total	35(100.0)	22(100.0)	57(100.0)	

Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID-19 (March 2018 – February 2019)	During COVID-19 (March 2020 – February 2021)		
Booking weight (kg), range and Median				0.580[m]
Minimum	43	36	36	
Maximum	563	117	563	
Median (IQR)	60[55 – 75]	76[47.75– 93.5]	54.5(53 – 85.25)	
Booking weight (kg)				0.378[f]
<90	14(40)	10(45.5)	24(42.1)	
≥90	2(5.7)	4(18.2)	6(10.6)	
Missing data	19(54.3)	8(36.4)	27(47.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Mid Upper Arm Circumference (cm), range, and median				0.790[m]
Minimum	21	20	20	
Maximum	245	39	245	
Median [IQR]	25[23 – 29.75]	24.5[21 – 35]	25(22.38-30.75]	
Mid Upper Arm Circumference (cm), range, and median				
≤22	3(8.6)	5(22.7)	8(14.0)	0.101[f]
23-33	11(31.4)	5(22.7)	16(28.1)	
≥34	1(2.9)	4(18.2)	5(8.8)	
Missing data	20(63.6)	8(36.4)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Height (cm)				0.505
Minimum	151	143	8	
Maximum	164	185	16	
Median [IQR]	155[152-162]	159.5[151-163]	5	
Height (cm)				
≤150	3(8.6)	2(9.1)	5(8.8)	1.000[f]
≥151	12(34.3)	12(54.5)	24(42.1)	
Missing data	20(57.1)	8(36.4)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
COVID-19				<0.001[f]
Yes	0(0.0)	9(40.9)	9(15.8)	
No	35(100.0)	13(59.1)	48(84.2)	
Total	35(100.0)	22(100.0)	57(100.0)	
Antenatal complications				0.906[c]
Present	15(42.9)	10(45.5)	25(43.9)	
Absent	14(40.0)	10(45.5)	24(42.1)	
Missing data	6(17.1)	2(9.1)	8(14.0)	
Total	35(100.0)	22(100.0)	57(100.0)	

Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID-19 (March 2018 – February 2020)	During COVID-19 (March 2020 – February 2021)	Total	
Antenatal complication types				0.107[f]
Unbooked	13(37.1)	4(18.2)	17(29.8)	
Preterm labour	1(2.9)	0(0.00)	1(1.8)	
Genital warts	1(2.9)	0(0.00)	1(1.8)	
Hypertension in pregnancy	5(14.3)	3(13.6)	8(14.0)	
Lower respiratory infection	3(8.6)	0(0.00)	3(5.3)	
*COVID-19	0(0.00)	4(18.2)	4(7.0)	
**Others	4(11.4)	4(18.2)	8(14.0)	
Missing data	8(22.8)	7(31.8)	15(26.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Management of antenatal complications met expectation				0.545[f]
Yes	7(20.0)	4(18.2)	11(19.3)	
No	2(5.7)	4(18.2)	6(10.6)	
Sometimes	6(17.1)	4(18.2)	10(17.5)	
Missing data	20(57.1)	10(45.5)	30(52.6)	
Total	35(100.0)	22(100.0)	57(100.0)	

*Of the 9 women diagnosed with COVID-19, a total of 4 were diagnosed during the antenatal period.

**Others were women who had more than one complication. Anemia was defined as a hemoglobin concentration less than 11g/dl in the first trimester. Abbreviations: c, Chi-square test; f, Fisher exact test; m, Mann-Whitney U test.

More than half of the women (66.7%, 38/57) had a pre-existing chronic medical condition before pregnancy with the most common being HIV infection (61.4%, 35/57). Of the women living with HIV infection, the median CD4 count (cells/μl) was 312 (IQR 39–459), comprising 116 (11.5–378) before and 331 (197–667) during COVID-19-P, p = 0.133. Of the 35 women with HIV infection 19 (54.3%) were on antiretroviral therapy: 12/35 before and 7/22 during COVID-19-P. The second most common chronic condition was chronic hypertension which occurred in 5.3.% (3/57) of all the women (two before and one during COVID-19-P).

The most frequent antenatal complication that developed after booking was hypertensive disorders of pregnancy (HDP) and this occurred in 14.3% (5/35) and 13.6% (3/22) of the women before and during COVID-19-P, respectively. The second most common antenatal complication was COVID-19, which occurred in 7.0% (4/57) of all the women but, understandably, there was none before the COVID-19 period. Overall, 9 (15.8%) women had COVID-19 in total (Table 2). Except for COVID-19, there was no statistical difference between the two study periods in terms of the antenatal profile, COVID-19 status, and chronic medical condition (Table 2).

3.3 Trends in maternal deaths, births, and maternal mortality ratio

The trends in MDs and live births during the four-year study period are summarized in Table 3. Of the 58 MDs, 60.34% (35/58) occurred before and 39.66% (23/58) during COVID-19-P. The live births increased from 5 166 in the first year of the study, reaching a peak of 5 947 in the third year (March 2020 to February 2021) and thereafter declining to 5 476 in the fourth year. There was also a steady decline in MDs from 17 to 11 during the four-year period. Similarly, the iMMR decreased steadily from 329.07 to 200.88 deaths per 100 000 live births (Fig 2).

Table 3. Twelve-monthly trends in maternal deaths, live births, and maternal mortality ratio

Variables	Before COVID-19		During COVID-19	
	Mar 2018 – Feb 2019	Mar 2019 – Feb 2020	Mar 2020 – Feb 2021	Mar 2021 – Feb 2022
Maternal deaths	17	18	12	11
Live births	5166	5866	5947	5476
Total births	5333	6070	6153	5647
Maternal mortality ratio per 100 000 live births	329.1	306.9	201.8	200.9

Overall, the maternal mortality ratio per 100 000 live births was 317.3 before COVID-19, 201.3 during COVID-19 and 258.3 during the 4-year period of the study.

Fig 2. Twelve-monthly trends in maternal mortality ratio

Abbreviations: Feb, February; Mar, March.

Table 4 shows the six-monthly MDs, deliveries, and iMMR across 8-point periods. The jointpoint regression analysis of the six-monthly iMMR showed a statistically significant declining trend of 9.59% between February 2018 - August 2018 and September 2021 – February 2022 (Fig 3). The six-monthly trends in iMMR are shown in Fig 4.

Table 4. Six-monthly maternal deaths, deliveries, births, and maternal mortality ratio

Period	Maternal deaths	Total deliveries	Total births	Total live births	Maternal mortality ratio per 100 000 live births
Before COVID period					
Feb 2018 – Aug 2018	10	2685	2720	2632	379.9
Sep 2018 – Feb 2019	7	2571	2613	2534	276.2
Mar 2019 – Aug 2019	11	2942	2979	2884	381.4
Sep 2019 – Feb 2020	7	2956	3091	2982	234.7
During COVID-19 period					
Mar 2020 – Aug 2020	6	3126	3188	3090	194.2
Sep 2020 – Feb 2021	6	2920	2965	2857	210.0
Mar 2021 – Aug 2021	6	2865	2906	2816	213.1
Sep 2021 – Feb 2022	5	2689	2741	2760	181.2

Fig 3. Jointpoint regression analysis of the six-monthly maternal mortality ratio

Explanation: The Annual percentage change (APC) denotes six monthly percentage change. There were 8 time periods of six months each: 1 – 8 (square dots), consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

Fig 4. Six-monthly trends in maternal mortality ratio

Explanation: Abbreviation: MMR, Maternal mortality ratio. There were 8 time periods 1 - 8, consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

3.4 Intra- and post-partum outcomes and their complications

There was no statistically significant difference between the two periods in terms of intra- and post-partum outcomes and their complications (Table 5). Nonetheless, 40.4% (23/57) of the women delivered vaginally (16/35 before and 7/22 during COVID-19-P) compared to 33.3% (19/57) who delivered via caesarean delivery (9/35 before and 10/22 during COVID-19-P). A respective total of 21% (12/57) and 5.3% (3/57) were undelivered and had a laparotomy for ectopic pregnancy. The most common indication for caesarean delivery was fetal distress which occurred in 12.2% (7/57) of the women with 4/35 before and 3/22 during COVID-19-P.

Table 5. Intra- and post-partum outcomes and their complications

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID (March 2018 – February 2020)	During Covid (March 2020 – February 2021)	Total	
Mode of delivery n (%)				0.266[f]
Vaginal birth	16(45.7)	7(31.8)	23(40.4)	
Caesarean delivery	9(25.7)	10(45.5)	19(33.3)	
Undelivered	7(20.0)	5(22.7)	12(21.0)	
Laparotomy for ectopic pregnancy	3(8.6)	0(0.00)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Blood loss (ml) during childbirth, range and median				0.845[m]
Minimum	50	200	50	
Maximum	2000	1100	2000	
Median [IQR]	500[200 – 950]	500[250– 1000]	500[275– 1000]	
Blood loss (ml) during childbirth, n (%)				0.413[f]
≤499	6(17.1)	3(13.6)	9 (15.8)	
500 – 999	4(11.4)	3(13.6)	7(12.3)	
1000 – 1499.9	1(2.9)	3(13.6)	4(7.0)	
≥1500	2(5.7)	0(0.00)	2(3.5)	
Missing data	22(62.9)	13(59.1)	35(61.4)	
Total	35(100.0)	22(100.0)	22(100.0)	
Apgar score				0.116[m]
Minimum	0	0	0	
Maximum	10	10	10	
Median (IQR)	7.5[0 – 9]	9 [6.25 – 10]	8[0-10]	

Table 5 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Apgar score category, n (%)				
Stillbirth (0)	0(0.0)	0(0.0)	0(0.0)	Constant
Asphyxia (1 - 6)	0(0.0)	0(0.0)	0(0.0)	
Normal Apgar (≥7)	15((42.9)	14(63.6)	29 (50.8)	
Undelivered	7(20)	5(22.7)	12(21.0)	
Ectopic laparotomy	3(8.6)	0(0.0)	3(5.3)	
Missing data	10(28.5)	3(13.6)	13(22.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Birth weight (g)				0.226[m]
Minimum	450	890	450	
Maximum	3400	3400	3400	
Median, IQR	1850[1187.5 – 2625]	2400[1395 – 3000]	2130[1300 – 2750]	
Birth weight (gram) category, n (%)				0.563[f]
≤999g	4(11.4)	1(4.5)	5 (8.8)	
1000-2499 g	8(22.9)	6(27.3)	14 (24.6)	
≥2500 g	6(17.1)	6(27.3)	12 (21.0)	
Missing data	17(48.6)	9(40.9)	26(45.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Gender of baby, n (%)				0.755[c]
Male	10(28.6)	7(31.8)	17(29.8)	
Female	8(22.9)	7(31.8)	15(26.3)	
Undelivered	7(20.0)	5(22.7)	12(21.0)	
Ectopic pregnancy	3(5.3)	0(0.0)	3(5.3)	
Missing data	7(20.0)	3(5.3)	10(28.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Intrapartum complications, n(%)				0.013[f]
Yes	0	4(18.2)	4(7.0)	
No	26(74.3)	11(50.0)	37(64.9)	
Missing data	9(25.7)	7(31.8)	16(28.1)	

Table 5 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Postpartum complications, n (%)				0.859[c]
Yes	17(48.6)	12(54.6)	29(50.9)	
No	8(22.9)	5(22.7)	13(22.8)	
Missing data	10(28.6)	5(22.7)	15(26.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of postpartum complication, n (%)				0.349[f]
Postpartum hemorrhage	4(11.4)	2(9.1)	6(10.5)	
Puerperal Sepsis	5(14.3)	1(4.5)	6(10.5)	
Venous thromboembolism	1(2.9)	2(9.1)	3(5.3)	
Cardiac arrest during caesarean delivery	2(5.7)	1(4.5)	3(5.3)	
Preeclampsia with severe features	4(11.4)	3(13.6)	7(12.3)	
Perforated Uterus	1(2.9)	0(0.00)	1(1.8)	
COVID-19	0(0.00)	3(13.6)	3(5.3)	
No complication	18(51.5)	10(45.6)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: c, Chi-square test; f, Fisher exact test; m, Mann-Whitney U test.

The median APGAR score for the two periods was 8 (0−10) comprising 7.5 (0−9) before and 9 (6.25−10) during COVID-19-P, p = 0.116. The median birth weight (g) for the babies of the women in the two periods was 2 130 (1 300–2 750) comprising 1 850 (1 187.5–2 625) before and 2 400 (1 395–3 000) during COVID-19-P, p = 0.226. The most common postpartum complications before COVID-19-P were puerperal sepsis 14.3% (5/35), postpartum hemorrhage (PPH) 11.4 (4/35), and preeclampsia with severe features 11.4% (4/35). During the COVID-19-P, the most common postpartum complications were COVID-19 13.6% (3/22), preeclampsia with severe features 13.6% (3/22), and postpartum haemorrhage (PPH) 9.1% (2/22). There was no significant intrapartum complication during the period under study

3.5 Critical care admissions and mechanical ventilation

Table 6 shows critical care admissions and mechanical ventilation. More percentage of women, 38.1% (8/22), were admitted to the high care unit during COVID-19-P compared to 31.4% (11/35) before the pandemic. Before COVID-19-P, sepsis was the most common indication for high-care admission, occurring in 14.3% (5/35) of the women. However, during COVID-19-P, the most common indications for high-care admission were preeclampsia with severe features 9.1% (2/22) and cardiac diseases 9.1% (2/22).

Table 6. Critical care admissions and mechanical ventilation

Variable	Values n (%)			*p-value*
	Before COVID-19	During COVID-19	Total	
Admission to high care unit, n (%)				0.700[c]
Yes	11(31.4)	8(38.10)	19(33.3)	
No	24(68.6)	14(63.6)	38(66.7)	
Total	35(100.0)	22(100.0)	57(100.0)	
Indications for admission to high care unit, n (%)				0.418[f]
Preeclampsia with severe features	2(5.7)	2(9.1)	4(7.0)	
Postpartum haemorrhage	1(2.9)	1(4.5)	2(3.5)	
Sepsis	5(14.3)	1(4.5)	6(10.5)	
Cardiac diseases including supraventricular tachycardia	3(8.6)	2(9.1)	5(8.8)	
Other indications	0(00)	2(9.1)	2(3.5)	
Straight admission to ICU	24(68.6)	14(63.6)	38(66.7)	
Total	35(100.0)	22(100.0)	57(100.0)	
Admission to intensive care unit (ICU), n (%)				1.000[c]
Yes	25(71.4)	15(68.2)	40(70.2)	
No	10(28.6)	6(27.2)	16(28.0)	
Missing data	0 (0)	1(4.5)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Indication for admission to ICU, n (%)				0.151[f]
Acute respiratory distress	12(34.3)	8(36.4)	20(35.1)	
GCS of 7 and less	3(8.6)	3(13.6)	6(10.5)	
Inotropic support	9(25.7)	2(9.1)	11(19.3)	
Cardioversion	2(5.7)	0(0.00)	2(3.5)	
Fluid resuscitation	0(0.00)	2(9.1)	2(3.5)	
Not admitted to ICU	9(25.7)	7(31.8)	16(28.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Mechanical ventilation, n(%)				0.026[c]
Yes	25(71.4)	11(52.38)	36(63.1)	
No	7(20.0)	11(47.62)	18(31.6)	
Missing data	3(8.5)	0(00)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	

* Resuscitation describes women who were admitted to ICU to control central venous pressure. Abbreviations: GCS, Glasgow Coma Scale.

c: Chi-square test; f: Fisher exact test.

The proportion of women admitted to the intensive care unit (ICU) was 71.4% (25/35) before and 68.2% (15/22) during COVID-19-P. The most common indications for ICU admission were acute respiratory distress at 34.3% (12/35) before and 36.4% (8/22) during COVID-19-

P, p = 0.151. The rate of mechanical ventilation was 74.3% (26/35) before and 52.38% (11/22) during COVID-19-P (p = 0.026).

3.6 Time of hospital admission and hour of maternal death

Table 7 shows the time of hospital admission and hour of MDs, with no statistically significant difference between the periods before and during COVID-19-P, p>0.05. Most hospital admissions occurred during the day. However, the majority of MDs occurred during the night: 74.3% (26/36) before and 59.1% (13/22) during COVID-19-P, p = 0.494. Most of the MDs occurred outside the Obstetrics and Gynaecology department, 81.8% before and 87.7% during COVID-19-P.

Table 7. Time of hospital admission and maternal death

Variable	Values n (%)			*p*-value
	Before COVID-19	During COVID-19	Total	
Time of hospital admission, n (%)				0.192[f]
Day (08:00 - 15:59 hours)	20(57.1)	7(31.8)	27(47.4)	
Evening (16:00 - 18:59 hours)	6(17.1)	5(22.7)	11(19.3)	
Night (19:00 - 07:59 hours)	9(25.7)	10(45.5)	19 (33.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Time of death, n (%)				0.494[f]
Day (08:00 - 15:59 hours)	5(14.3)	5(22.7)	10(17.5)	
Evening (16:00 - 18:59 hours)	4(11.4)	4(18.2)	8(14.1)	
Night (19:00 - 07:59 hours)	26(74.3)	13(59.1)	39(68.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Department where death occurred, n (%)				0.411[f]
Within Obstetrics and Gynaecology Department	3(8.6)	4(18.2)	7(12.3)	
Outside Obstetrics and Gynaecology Department But including ICU Setting	32(91.4)	18(81.8)	50(87.7)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: c, Chi-square test; f, Fisher exact test; ICU, intensive care unit

3.7 Primary and final causes of maternal deaths

Table 8 shows the primary and final causes of MDs. Preeclampsia with severe features (22.9%) was the most common primary cause of MDs before COVID-19-P, with tuberculosis being second (20%), early pregnancy bleeding third (17.2%), and sepsis fourth (14.3%). Conversely, COVID-19 (31.8%), and tuberculosis (13.6%) were the first and second most common primary causes of MDs during the COVID-19-P, with the third most common cause being four conditions namely PPH, pulmonary embolism, sepsis and preeclampsia with severe features, each having a percentage occurrence of 9.1%. The primary causes of MD for the two periods ($p = 0.009$), however, were statistically significantly different.

Table 8. Causes of maternal deaths

Variable	Values n (%)			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Primary causes of death				0.009[f]
Postpartum haemorrhage	2(5.7)	2(9.1)	4(7.0)	
Pulmonary embolism	2(5.7)	2(9.1)	4(7.0)	
Tuberculosis	7(20)	3(13.6)	10(17.5)	
Sepsis	5(14.3)	2(9.1)	7(12.3)	
Early pregnancy bleeding	6(17.2)	0(0.00)	6(10.5)	
Preeclampsia with severe features	8(22.9)	2(9.1)	10(17.5)	
COVID-19	0(0.00)	7(31.8)	7(12.3))	
*Others	5(14.3)	4(18.2)	9(15.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Final causes of death				0.092[f]
Cardio-pulmonary arrest	11(31.4)	11(50.0)	22(38.6)	
Respiratory failure	7(20)	6(27.3)	13(22.8)	
Renal failure	1(2.9)	1(4.5)	2(3.5)	
Liver Failure	0(0.00)	1(4.5)	1(1.8)	
Multiple organ Failure	16(45.7)	3(13.6)	19(33.3)	
Total	35(100.0)	22(100.0)	57(100.0)	

*Others comprised Kaposi sarcoma, advanced cervical cancer, suicide, ingestion of unsafe herbal medication, parasuicide, and supraventricular tachycardia. Early pregnancy bleeding includes those from ectopic pregnancy, miscarriages, and termination of pregnancy. Abbreviations: c, Chi-square test; f, Fisher exact test.

The most common final causes of MDs before and during COVID-19-P were multiple organ failure (45.7%) and cardiopulmonary arrest (50%); however, there was no statistically significant difference in the final causes of MDs between the two periods (p = 0.092).

3.8 Avoidable factors

The patient-, healthcare professional- and administrative-related AVFs associated with the MDs are presented in Table 9. Each woman had at least one AVF that was associated with her management. Before COVID-19-P, patient, healthcare professional, and administrative-related AVFs occurred in 62.9% (22/35), 62.9% (22/35), and 57.1% (20/35) of the women,

respectively. Before COVID-19-P, the most common patient-, healthcare professional- and patient-related AVFs were not having any antenatal care, wrong treatment, and lack of ICU/high care beds respectively.

Table 9. Patient, healthcare worker, and administrative-related avoidable factors

Avoidable factor (AVF)	Values n (%)			*p*-value
	Before COVID-19	During COVID-19	Total	
Presence of any AVF, n (%)				
Present	35(100.0)	22(100.0)	57(100.0)	
Absent	0(0.0)	0(0.0)	0(0.0)	
Total	35(100)	22(100)	57(100.0)	
Patient-related AVF, n (%)				1.000
Present	22(62.9)	8(36.4)	30(52.6)	
Absent	13(37.1)	14(63.6)	27(47.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Types of patient-related avoidable factors, n				
Had no antenatal care	13	3	16	
Defaulted antenatal clinic	0	1	1	
Refused medical treatment	0	0	0	
Commenced antenatal clinic after 20 weeks' gestation	6	1	7	
Declined medical treatment	2	2	4	
Delayed seeking medical treatment	11	4	15	
Unsupervised delivery at home	1	1	2	
Total	33	12	45	
Healthcare professional related AVF, n (%)				0.272
Present	22(62.9)	12(54.5)	34(59.6)	
Absent	13(37.1)	10(45.5)	23(40.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of healthcare professional-related AVF, n				
Lack of critical care skills	7	4	11	
Delay in referral	7	2	9	
Wrong diagnosis despite classical features of a disease	6	1	7	
Total	34	12	46	
Administrative-related AVF, n (%)				0.779
Present	20(57.1)	11(50.0)	31(54.4)	
Absent	15(42.9)	11(50.0)	26(45.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of administrative-related AVF, n				
Delay in referral (transportation)	7	1	8	
Communication breakdown	5	3	8	
Lack of equipment	2	0	2	
Lack of trained medical staff	4	0	4	
Lack of ICU and high care dependent unit space	11	7	18	
Lack of medicine	0	1	1	
Total	29	12	41	
Wrong treatment	10	2	12	
Delay in seeking senior outputs	4	3	7	

Multiple avoidable factors were associated with the management of some patients, and this made the calculation of percentages of the type of avoidable factor less informative. Additionally, some avoidable factors may be grouped into more than one category; however, the current grouping in this table was based on specific circumstances associated with each case after a robust panel discussion. Abbreviations: c, Chi-square test.

During COVID-19-P, patient-, healthcare professional- and administrative-related AVFs occurred in 36.4% (8/22), 54.5% (12/22), and 50% (11/22) of the women, respectively. In the same period, the most common patient-, healthcare professional- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability of ICU/high care beds, in this order.

Table 10 shows the AVFs associated with the management of causes of the MDs. The conditions associated with the greatest number of AVFs were pregnancy-related infection and HDP. The most common AVF associated with non-pregnancy-related infections was poor compliance to antiretroviral drugs: with frequencies of 12 before and eight during COVID-19-P. The most frequent AVF associated with the management of HDP was delay in referral to a tertiary hospital: 10 before and four during COVID-19-P.

Table 10. Avoidable factors associated with management of causes of maternal death

Avoidable factors	Values, n		
	Before COVID-19	During COVID-19	Total
Avoidable factors related to non-pregnancy-related infection, n	14	10	24
Defaulted TB treatment multiple times	8	3	11
CD4 not checked by a healthcare worker	6	5	11
Poor compliance to ARV treatment	12	8	20
Avoidable factors related to hypertensive disorders of pregnancy, n	13	6	19
Delay in referral to tertiary hospital	10	4	14
Pre-eclampsia screening test not performed healthcare worker	9	2	11
Avoidable factors related to obstetric haemorrhages, n	5	3	8
Problem recognition of bleeding ectopic pregnancy	3	0	3
INR not requested in IUFD	1	0	1
Poor surgical skills at caesarean delivery	1	1	2
Delay in taking a relook decision	0	2	2
Avoidable factors related to puerperal sepsis	4	1	5
Problem recognition of puerperal sepsis	1	0	1
Delay in deciding to perform TAH	1	0	1
Problem recognition of RPOC	1	0	1
Avoidable factors related to ectopic pregnancy.	2	1	3
Obvious features of ectopic pregnancy misdiagnosed and the patient received misoprostol for termination of pregnancy on request until shock	0	1	1
Classical features of ectopic pregnancy missed at the medical ED where the patient was brought for symptomatic anemia and urine beta hCG test was not performed	1	0	1
Classical features of ectopic pregnancy missed treated as pelvic inflammatory disease in pregnancy	1	0	1
Avoidable factors related to medical and surgical conditions	9	4	12
Suicide	0	1	1
Late presentation of advanced cervical cancer in pregnancy	2	1	3
Failure to refer cardiac patients to a higher level of care	2	2	4
Inadequate critical care	4	0	4
Delay in diagnosis of obvious pelvic source of sepsis in the medical ward	1	0	1

Multiple avoidable factors were associated with the management of some patients. Additionally, some avoidable factors may be grouped into more than one category; however, the current grouping in this table was based on specific circumstances associated with each case after a robust panel discussion. Abbreviations: ARV, Anti-retroviral drugs; ED, Emergency Department; INR, International normalized ratio; IUFD, Intrauterine fetal death; RPOC, Retained product of conception; TAH, Total abdominal hysterectomy; TB, Tuberculosis.

4. Discussion

4.1 Main findings

The number of MDs and iMMRs was more before than during COVID-19-P. Both the MDs and iMMR decreased yearly during the study period, with a 9.59% declining trend in the six-monthly iMMR between the first and last six months of the study period. The first, second, and third most common causes of MDs before COVID-19-P were preeclampsia with severe features, tuberculosis, and early pregnancy bleeding, in this order. During COVID-19-P, the first and second most common causes of MD were COVID-19 and tuberculosis, respectively, with the former attributable to 31.8% (7/22) deaths. The third most common causes of MD during COVID-19-P were PPH, pulmonary embolism, sepsis, and preeclampsia with severe features. The percentage of the women who had mechanical ventilation was statistically significantly more before than during the COVID-19-P. Most MDs occurred at night, with most hospital admissions occurring during the day.

Avoidable factors were associated with all the MDs. Before COVID-19-P, the most frequent patient-, healthcare professional-, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care bed spaces, respectively. During COVID-19-P, the most common patient-, healthcare worker- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability of ICU/high care bed spaces, respectively.

4.2 Interpretation

Most of the women who died were between the ages of 25 and 34. The predominant age group in this study was similar to the findings of Thomas et al. where participants were between the ages of 14 and 45 [17]. Contrary, Rulisa et al. found that the most common age group was 16

- 57 years [18]. In non-pregnant adults, however, death due to COVID-19 affected mainly individuals aged 60 years and above [19].

In South Africa, some patients access healthcare across health districts due to reasons such as referral patterns, logistical concerns, and financial cost considerations [20]. In this study setting, the restriction of movements during the COVID-19 period did not affect the total deliveries and births because there were no decline in their rates (Tables 3 and 4). However, Bailey et al 2023 reported an increase in birth rates among native Americans during the COVID-19-P [21]. In contrast, Wachuli et al. found that COVID-19 severely impacted maternity services in their setting and was associated with a reduction in the number of antenatal care revisits [22]. However, the index study setting was a referral centre that prioritized maternity services. Since most of the deceased were from the same district (Kenneth Kaunda) as the study setting, restrictions in movement/transportation might not have impacted the referral pattern before and during COVID-19-P.

Surprisingly, there was a decline in MDs and iMMR during COVID-19-P as compared to the period before COVID-19. In South Africa, the overall iMMR per 100 000 live births was 98.8 in 2019 (before COVID-19-P), 126.1 in 2020, 148.1 in 2021, 109.9 in 2022, and 102.1 in 2023 [23]. Compared to the pre-pandemic levels, COVID-19 caused an increase in iMMR in 2020 and 2021 but there was a decline observed in 2022 [23]. Similarly, Beňová et al reported an increase in iMMR during the COVID-19-P [24]. Most plausibly, the decline in MD and iMMR at the index study setting, despite the occurrence of COVID-19-P, might be because of continuous and sustained improvement in maternity care at the facility. The number of full-time specialist obstetricians and gynaecologists doubled from two to four in 2019 and was retained. Moreover, additional clinical staff were allocated to essential services such as

maternity care during the COVID-19-P. Nonetheless, the differences in the clinical profile of patients, coupled with the virulence of the SARS-COV-2 strain and other supportive care, might also have played a role in the differences in trends observed at various settings by different researchers. For instance, the rate of mechanical ventilation was lower during than before COVID-19-P. Given that COVID-19 is a highly infectious respiratory disease, the lower rate of mechanical ventilation during the pandemic, may indicate that the deceased pregnant women who presented with COVID-19 in the study setting did not have severe respiratory complications requiring mechanical ventilation.

Notably, the first, second, and third most common causes of MDs before COVID-19-P were preeclampsia with severe features, tuberculosis, and early pregnancy bleeding, respectively. This is similar to the findings of another study showing that among the most common causes of MDs before COVID-19-P were sepsis, haemorrhage such as those from abortion, and HDP particularly preeclampsia [18]. During COVID-19-P, the first most common cause of MD was COVID-19, with tuberculosis being the second. Similar to our findings, the most common causes of MDs during COVID-19-P have been reported by other investigators as COVID-19 pneumonia and associated acute respiratory distress [25].

All the MDs were associated with an AVF, which could possibly have prevented some of the deaths. This information re-echoes the findings of the National Committee on Confidential Enquiry into Maternal Deaths in South Africa which showed that 58% of the MDs in South Africa had been preventable [23]. During the COVID-19-P, the most common patient, healthcare professional, and administrative-related AVFs in our study were delay in seeking medical treatment, lack of critical care skills, and lack of ICU/high care dependent unit bed spaces, respectively. Before the COVID-19 period, though, the most frequent patient,

healthcare professional, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care dependent unit bed spaces, respectively. Notably, some of the AVFs were related to a specific clinical condition (Table 10), and this becomes a clarion call for development and adherence to clinical protocols. This need has been highlighted by Sadler et al. who showed that the management of obstetric conditions such as puerperal sepsis and PPH was associated with substandard care and lack of problem recognition [26].

4.3 Strengths and limitations

There were some missing data because of the retrospective design of the study. To address this limitation, missing data were reported and excluded from the calculation of p-values. The results of the histopathological autopsies were not available to the investigators, because in South Africa forensic autopsies are usually conducted for MDs and the reports are only made available to the family members of the deceased. Moreover, there was a restriction in performing histopathological autopsy during the early period of COVID-19-P due to concerns about disease spread. Furthermore, data on any MD that may have occurred outside the hospital setting such as at home were not available, and we are therefore unable to provide further comments about them. Additionally, the non-inclusion in the study of pregnant women who survived (including those with near misses) did not allow for comparison of the outcomes (diagnosis and interventions) in the deceased and survivors. However, our study design is acceptable, as MD analysis in many countries often does not include survivors [10, 23].

A major strength of our study is its comparative design, and the relatively long duration (four years) studied. This study is therefore among a few with these attributes, particularly among those conducted in low- and middle-income countries. Furthermore, the medical records of the

MDs were discussed by the investigators during scheduled meetings to ensure the appropriateness of the data collected. This approach prevents bias during data collection.

4.4 Recommendations and generalizability

The following are measures that may be implemented at the study setting and similar healthcare facilities to improve care. Firstly, staff training is required to prevent healthcare professional-related AVFs. Among the required training are critical care skills as well as diagnosis and treatment of common causes of MDs. Clinical staff should be rostered to undergo practical simulated training in common obstetric conditions. An example is the Essential Steps in Managing Obstetric Emergencies training.

Secondly, there is a need to streamline administrative factors by improving the healthcare system. Notable among them is the need to provide additional bed spaces for women needing critical care. Thirdly, there is a need to retain staff to avoid losing the gains made (declining iMMR). This may be in the form of seamless human resource services to staff and improving other conditions of services that will facilitate staff growth. Fourthly, there is a need to investigate the preponderance of MDs that occur at night to develop measures to address factors associated with them. It is possible that the nocturnal MDs may be partly related to poor staffing at night because there are already afternoon and weekend specialist handover ward rounds at the study setting. Fifthly, it is crucial to educate pregnant women about the need for antenatal care. In South Africa, over 68.3% of pregnant women attend antenatal care before 20 weeks of pregnancy [27]; however, there is a need to aim at a 100% uptake. The use of community-based healthcare workers and preventing barriers to access to prenatal care will improve antenatal clinic attendance [5, 28].

5. Conclusion

The iMMR was lower during than before the COVID-19 period, with a steady yearly decline. Improved resource availability (particularly employment of specialist clinical staff before COVID-19-P) and the preferential resource allocation to maternity services during the pandemic may be responsible for the decline in the iMMR. Therefore, a major determinant of the outcome of a clinical condition is the implementation of appropriate interventions.

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No fund was received to conduct this study or publish its findings.

Conflict of interest

None

References

1. Ngene NC, Onyia CO, Chigbu CO, Chauke L. Delay in managing benign gynaecological conditions in women of reproductive age during the COVID-19 pandemic in low-and middle-income countries. Case Rep Womens Health 2021;31:e00314. doi: https://doi.org/10.1016/j.crwh.2021.e00314.

2. Ngene NC, Moodley J. COVID-19 death: A novel method of improving its identification when a patient has multiple diagnoses. S Afr J Infect Dis. 2022;37(1). doi: https://doi.org/10.4102/sajid.v37i1.349.
3. World Health Organization. WHO Coronavirus (COVID-19 Dashboard 2024. Available from: https://data.who.int/dashboards/covid19/deaths?n=c (accessed 23 December 2024).
4. Global Change Data Lab. South Africa: What is the cumulative number of confirmed cases? 2024: Available from: https://ourworldindata.org/coronavirus/country/south-africa?country (accessed 22 December 2024).
5. Ngene NC, Khaliq OP, Moodley J. Inequality in health care services in urban and rural settings in South Africa. Afr J Reprod Health. 2023;27(5s):87-95. doi: https://doi.org/10.29063/ajrh2023/v27i5s.11.
6. Timeslive. Health Minister cancels Covid-19 face masks and travel certificates 2022 South Africa; June 23. Available from: https://www.timeslive.co.za /news/south-africa/2022-06-23-health-minister-cancels-covid-19-face-masks-and-travel-certificates/ (accessed 9 September 2024).
7. Roknuzzaman A, Sarker R, Nazmunnahar, Shahriar M, Mosharrafa RA, Islam MR. The WHO has Declared COVID-19 is No Longer a Pandemic-Level Threat: A Perspective Evaluating Potential Public Health Impacts. Clin Pathol . 2024;17. doi: https://doi.org/10.1177/2632010x241228053.
8. Ding W, Wang Q, Zhang J. Analysis and prediction of COVID-19 epidemic in south Africa. ISA Trans. 2021;8(9).doi: https://doi.org/10.1016/j.isatra.2021.01.050.
9. Jassat W, Cohen C, Tempia S. Risk factors for COVID-19-related in-hospital mortality in a high HIV and tuberculosis prevalence setting in South Africa. The Lancet HIV. 2021;8(9). doi: https://doi.org/10.1016/S2352-3018(21)00151-X

10. South African Department of Health. Saving Mothers and Babies 2017-2019: Executive Summary. Final report the effect of the first wave of Covid-19 on use of maternal and reproductive health services and maternal and perinatal deaths in South Africa 2020. Available from: https://www.health.gov.za/wp-content/uploads/2023/05/SAVING-MOTHERS-SAVING-BARIES-REPORT-2017-2019.pdf (accessed 23 December 2024).
11. Makinga PN, Moodley J, Titus MJ. The profile of maternal deaths in a district hospital: a five-year review of maternal deaths from 2006-2010. S Afr Fam Pract. 2012;54(6). doi: https://doi.org/10.1080/20786204.2011.10874059.
12. Smith-Sreen J, Miller B, Kabaghe AN, Kim E, Wadonda-Kabondo N, Frawley A, et al. Comparison of COVID-19 Pandemic Waves in 10 Countries in Southern Africa, 2020–2021. Emerg Infect Dis. 2022;28(13). doi: https://doi.org/10.3201/eid2813.220228.
13. Centre for Respiratory Diseases and Meningitis, NICD-NHLS. Proposed definition of COVID-19 wave in South Africa. 2021. Available from: https://www.nicd.ac.za/wp-content/uploads/2021/11/Proposed-definition-of-COVID-19-wave-in-South-Africa.pdf (accessed 23 December 2024).
14. Madhi SA, Kwatra G, Myers JE, Jassat W, Dhar N, Mukendi CK, et al. Sustained Low Incidence of Severe and Fatal COVID-19 Following Widespread Infection Induced Immunity after the Omicron (BA.1) Dominant in Gauteng, South Africa: An Observational Study. Viruses. 2023;15(3):597. doi: 10.3390/v15030597.
15. Maternal Death Inquiry-Ireland. Definition and classification of Maternal Death. University College Cork. 2021. Available from: https://www.ucc.ie/en/mde/definitionandclassificationofmaternaldeath/ (accessed 23 December 2024).

16. National Cancer Institute. Number of Joinpoints. 2024. Available from: Available from: https://surveillance.cancer.gov/help/joinpoint/setting-parameters/method-and-parameters-tab/number-of-joinpoints (accessed 22 September 2024).

17. Thomas TK, Umeokonkwo CD, Sesay HW, Adewuyi P, Babalola OJ, Wachekwa I, et al. Maternal mortality review in a major tertiary referral hospital in Liberia, 2018–2021. Heliyon. 2024;10(6):e28001. doi: https://doi.org/10.1016/j.heliyon.2024.e28001.

18. Rulisa S, Ntihinyurwa P, Ntirushwa D, Olufolabi A. Causes of Maternal Mortality in Rwanda, 2017-2019. Obstet Gynecol. 2021;138(4). doi: https://doi.org/10.1097/AOG.0000000000004534.

19. Wong MK, Brooks DJ, Ikejezie J, Gacic-Dobo M, Dumolard L, Nedelec Y, et al. COVID-19 Mortality and Progress Toward Vaccinating Older Adults - World Health Organization, Worldwide, 2020-2022. MMWR Morb Mortal Wkly Rep 2023;72(5):113-8. doi: https://doi.org/10.15585/mmwr.mm7205a1.

20. Neely H, Ponshunmugam A. A qualitative approach to examining health care access in rural South Africa. Soc Sci Med 2019;230:214-21. doi: https://doi.org/10.1016/j.socscimed.2019.04.025.

21. Bailey MJ, Currie J, Schwandt H. The COVID-19 baby bump in the United States. Proc Natl Acad Sci U S A 2023;120(34):e2222075120. doi: https://doi.org/10.1073/pnas.2222075120.

22. Wechuli VA, Karara MW, Wafula AT, Mayoka GW. Impact of COVID-19 on the Utilization of Maternal and Child Health Services at a Regional Referral Hospital in Kenya. Int J MCH AIDS. 2024;13:e008. doi: https://doi.org/10.25259/ijma_652.

23. South African Department of Health. National Committee for Confidential Enquiry into Maternal Deaths: Annual Report for 2023. Available from: https://www.health.gov.za/wp-content/uploads/2024/10/Saving-Mothers-Report-2023.pdf (accessed 24 December 2024).

24. Beňová L, Semaan A, Afolabi BB, Amongin D, Babah OA, Dioubate N, et al. Obstetric referrals, complications and health outcomes in maternity wards of large hospitals during the COVID-19 pandemic: a mixed methods study of six hospitals in Guinea, Nigeria, Uganda and Tanzania. BMJ Open 2023;13(9):e076364. doi: https://doi.org/10.1136/bmjopen-2023-076364.

25. Hessami K, Homayoon N, Hashemi A, Vafaei H, Kasraeian M, Asadi N. COVID-19 and maternal, fetal and neonatal mortality: a systematic review. J Matern Fetal Neonatal Med 2022;35(15):2936-41. doi: https://doi.org/10.1080/14767058.2020.1806817.

26. Sadler LC, Austin DM, Masson VL. Review of contributory factors in maternity admissions to intensive care at the new zeland tertiary hospital. Am J Obstet Gynecol 2013;209(6):549.el-7. doi: https://doi.org/10.1016/j.ajog.2013.07.031.

27. Myburgh N, Qwabi T, Shivambo L, Ntsie L, Sokani A, Maixenchs M, et al. Factors affecting antenatal care attendance in Soweto, Johannesburg: The three-delay model. Afr J Prim Health Care Fam Med.2024;16(1). doi: https://doi.org/10.4102/phcfm.v16i1.4333.

28. Ngene NC. Refusal of antenatal care and the applicable conceptual models. Case Rep Womens Health. 2019;22:e00110. doi: https://doi.org/10.1016/j.crwh.2019.e00110.

Supporting information captions

S1 Table. STROBE checklist for a cross-sectional study.

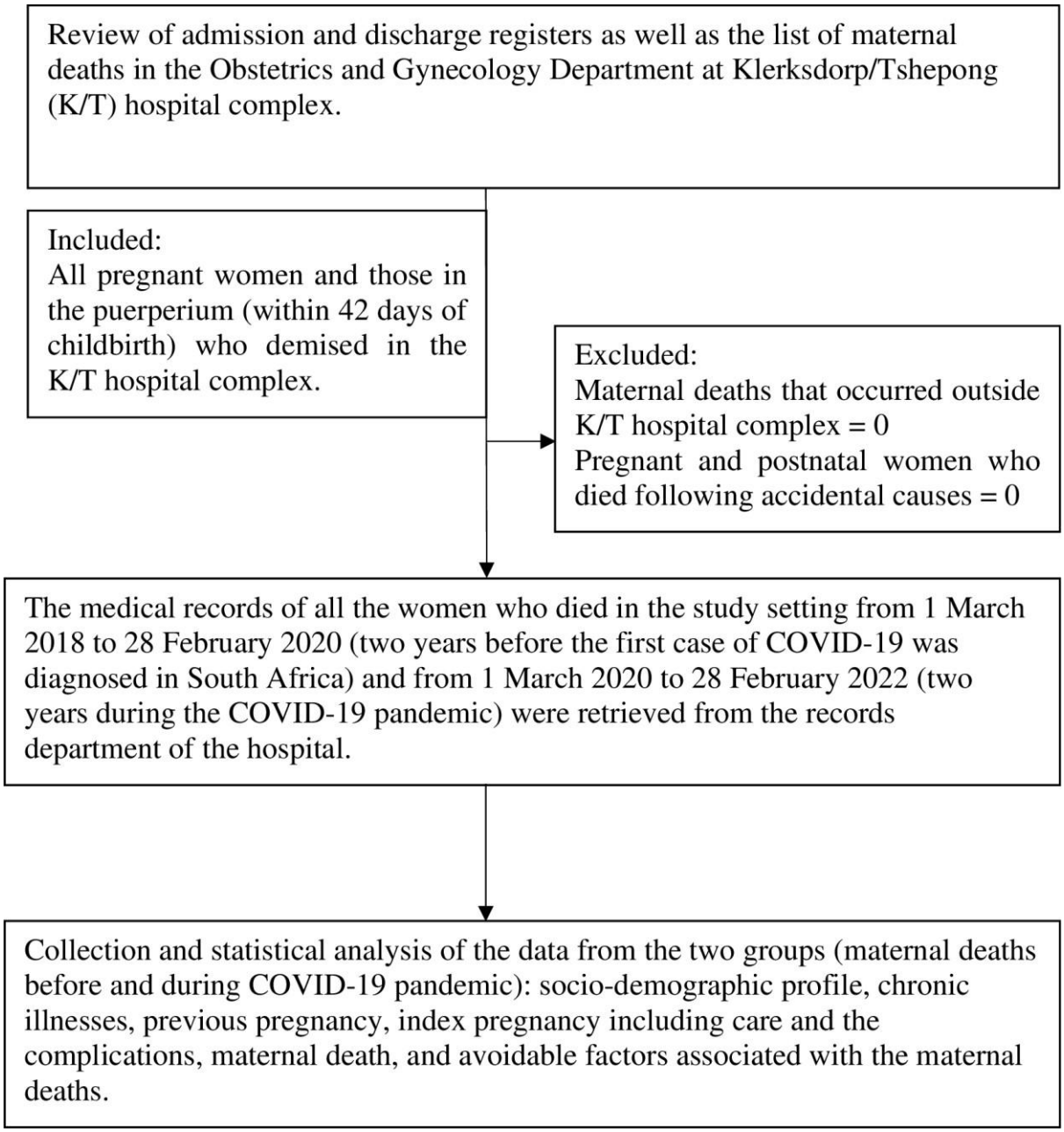


Fig 1. Flow diagram on data collection

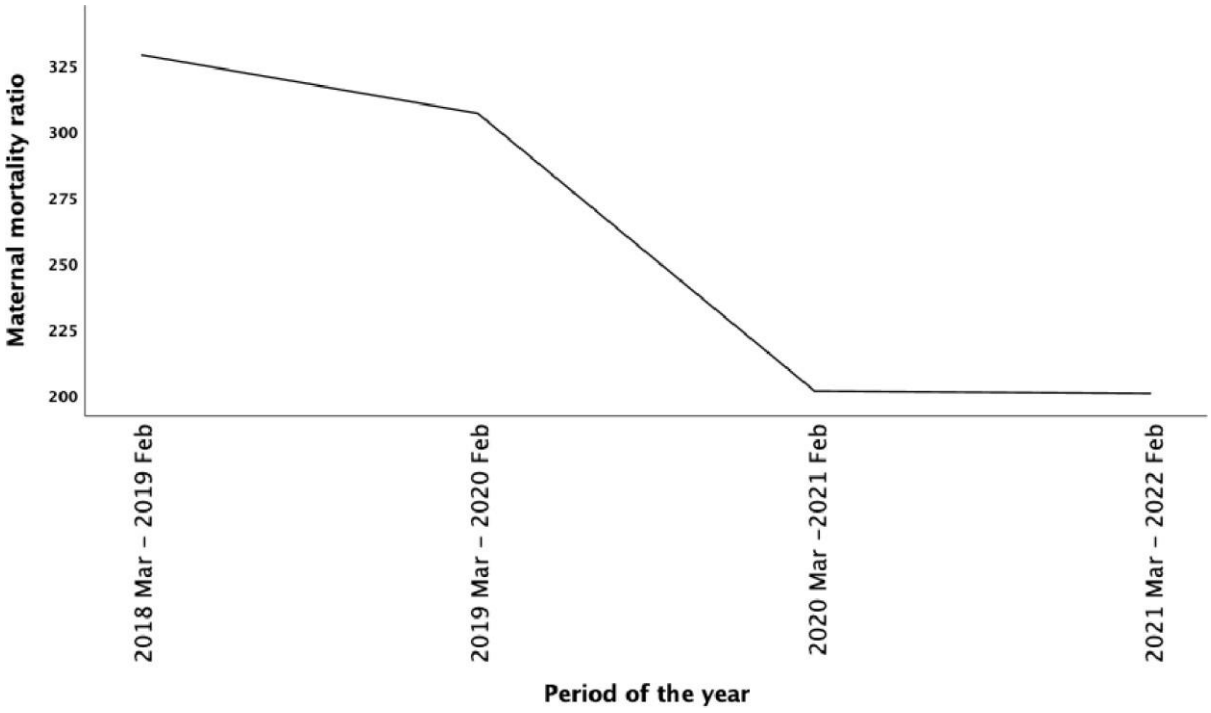


Fig 2. Twelve-monthly trends in maternal mortality ratio

Abbreviations: Feb, February; Mar, March.

Fig 3

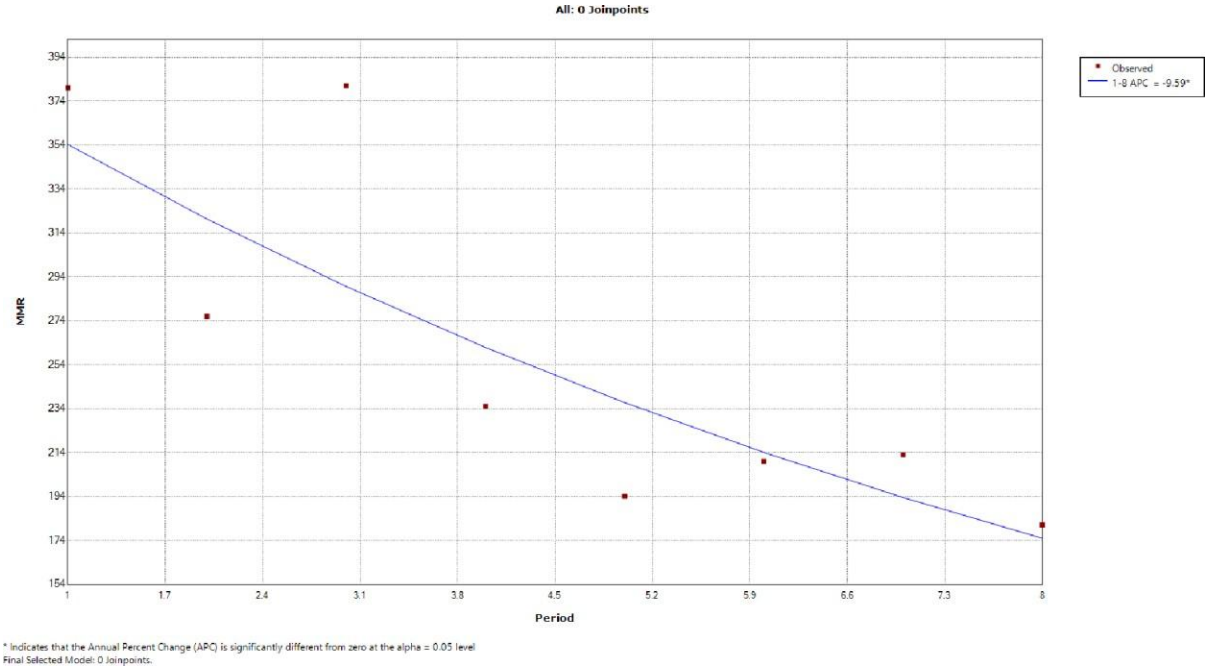


Fig 3. Jointpoint regression analysis of the six-monthly maternal mortality ratio

Explanation: The Annual percentage change (APC) denotes six monthly percentage change. There were 8 time periods of six months each: 1 – 8 (square dots), consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

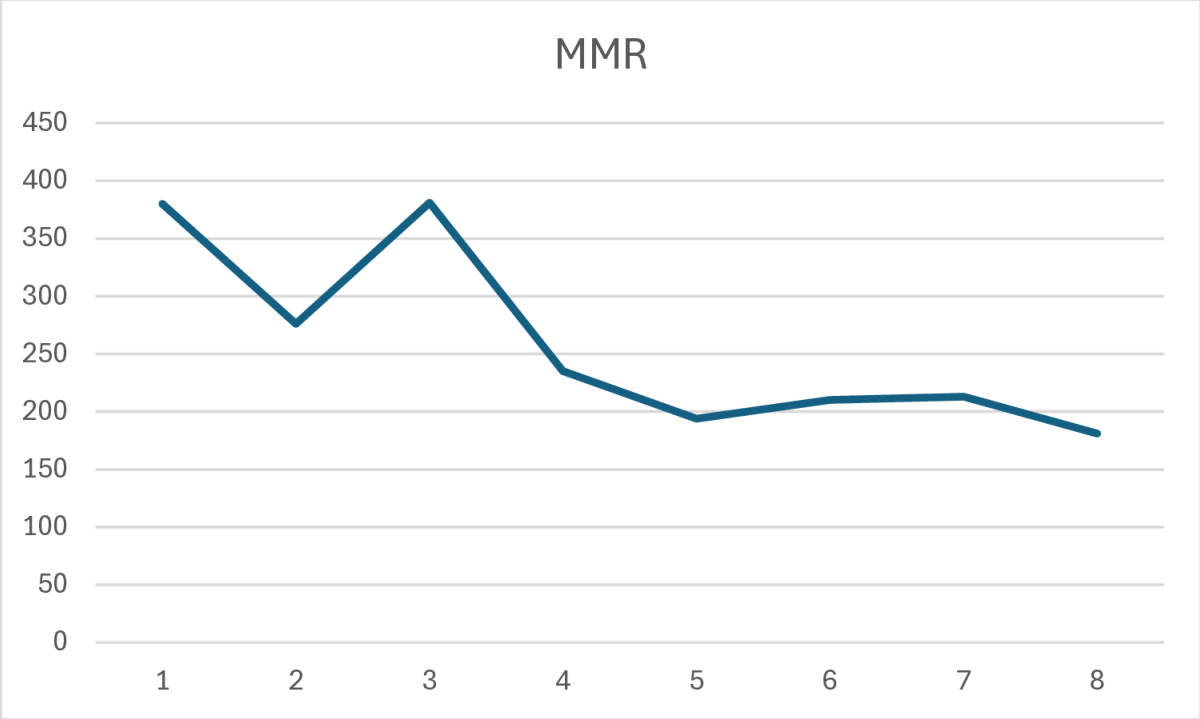


Fig 4. Six-monthly trends in maternal mortality ratio

Explanation: Abbreviation: MMR, Maternal mortality ratio. There were 8 time periods 1 - 8, consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

S1 Table. STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-31
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	7
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-31 35 - 36
		(b) Indicate number of participants with missing data for each variable of interest	9-31
Outcome data	15*	Report numbers of outcome events or summary measures	9-31
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	9-22
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A

Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	32
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	35-36
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	33-35
Generalisability	21	Discuss the generalisability (external validity) of the study results	36-37
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	37

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Appendices

APPENDIX 1: STUDY PROTOCOL

MATERNAL DEATHS BEFORE AND DURING COVID-19 PANDEMIC: CAUSES AND AVOIDABLE FACTORS IN A TERTIARY HOSPITAL IN SOUTH AFRICA

Registrar name:	Dr Ongombe Lunda
Student number:	2620318
Clinical department:	Obstetrics and Gynecology
Supervisor:	Dr NC Ngene
Co-Supervisor:	Dr G Deaf
Co-Supervisor:	Prof L Chauke

UNIVERSITY OF WITWATERSRAND 2021

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ART	Antiretroviral Therapy
COVID-19	Corona virus Disease 2019
CHCs	Community Health Clinics
DH	District Hospitals
HIC	High Income Country
HIV	Human Immunodeficiency Syndrome
K/T	Klerksdorp/Tshepong
LMICs	Low and middle-income country
NCCEMD	National Committee for the Confidential Enquiries into Maternal Deaths
NPW	Northwest Province
OR	Odds Ratio
SARS-CoV-2	Severe Acute Respiratory Syndrome Corona Virus-2
SA	South Africa
SPSS	Statistic Package for the Social Sciences
TB	Tuberculosis
WHO	Word Health Organisation
WHRREC	University of Witwatersrand Human Research

1.0 **INTRODUCTION**

1.2 Background

The maternal morbidity and mortality resulting from Corona virus disease 2019 (COVID-19) is devastating and yet to be fully controlled despite the availability of management strategies such as vaccination and non-pharmacological interventions including face masking, regular hand washing and social distancing. COVID-19 was first reported in China in the city of Wuhan on December 8, 2019.[1] It is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). On March 11, 2020, the World Health Organization (WHO) declared the disease a pandemic. The World Health Organization (WHO) declared the disease a pandemic on March 11, 2020.[1] In South Africa, the first case was reported in the province of KwaZulu-Natal on 6 March 2020.[2] The disease is highly infectious, has a high case fatality rate of 0.1 – 25%, and has resulted in over 4.95 million deaths worldwide as of 25 October 2021.[3] Many survivors of the disease are also battling to cope with the debilitating effects of long COVID. The pandemic has disrupted activities of daily living including the usual routines in the health sector and as a result, healthcare resources were redistributed in order to fight the pandemic.[4] Furthermore, COVID-19 death preferentially affects the vulnerable groups such as persons with comorbidity (including hypertension and diabetes) and those with immunosuppression as well pregnant women.[5] Consequentially, maternal deaths due to COVID-19 has increased globally including in south Africa.[6] [7]

In South Africa, pregnant women with severe COVID-19 are usually transferred to a regional or a tertiary hospital for further management. Despite this referral pattern, the contribution of COVID-19 to maternal deaths has not been extensively studied in South Africa particularly at tertiary hospitals. While South Africa collate data and publishes in-hospital or institutional maternal deaths every three years in her Saving Mothers Report[8] evidence suggests that the

commonest causes and trend in the maternal deaths at the national level (based on the consolidated data from various healthcare facilities) and a specific hospital may be different [9]. The latest 2017 - 2020 report included a section on COVID-19 and the data suggests that maternal deaths have increased during the first wave of COVID-19 pandemic in South Africa.[8] In Klerksdorp/Tshepong (K/T) Hospital, the only tertiary hospital in North West Province (NWP) in South Africa (SA), we do not know whether or not changes have occurred in number of maternal deaths during and prior to the COVID-19 pandemic, including the causes and avoidable factors associated with these deaths. The information may assist with the identification and implementation of interventions to prevent future maternal deaths.

1.2 Statement of the problem

Data published by the National Committee for the Confidential Enquiries into Maternal Deaths (NCCEMD) suggests that maternal deaths have increase nationally as a result of the COVID-19 pandemic.[8] We do not know if there has been a change in the maternal mortality ratio and the associated avoidable factors before and during the COVID-19 pandemic at K/T Hospital, the only tertiary healthcare facility in Northwest Province, South Africa. This province failed to achieve reduction in maternal mortality during the 2014-2016 triennium.[10]

1.3 Justification for the study

The COVID-19 pandemic has caused a huge number of human deaths world-wide and many of the deceased were pregnant or in the puerperium. Furthermore, resources have been preferentially diverted to fight the pandemic thereby restricting the provision of other healthcare services.[1] Unfortunately, the pandemic is on-going and maternal deaths (although less frequent) are still occurring. We do not know how the pandemic have affected maternal

mortality ratio in K/T hospital complex in North West Province, South Africa and what are the associated avoidable factors. Knowledge of this information may assist with the identification and implementation of interventions to prevent future maternal deaths.

1.4 Literature review

1.4.1 Definition of maternal death

Maternal death is the death of any woman during pregnancy or during the 42 days following the end of a pregnancy; and the death is related to or aggravated by the pregnancy including its management irrespectively of the site of the pregnancy, but excluding accidental or incidental causes.[11] On the other hand, late maternal death is defined as the death of a woman from direct or indirect obstetric causes between 42 days and one year following the end of a pregnancy.[12] Similar to late maternal deaths, the causes of maternal deaths can be either direct or indirect obstetric causes.

1.4.2 Causes of maternal death in South Africa

In South Africa, all the maternal deaths that occur during pregnancy and within 42 days postpartum are reported to the NCCEMD by each healthcare facility via the provincial health authority.[13] This data is published every three years in the form of South African Saving Mothers Report.

The commonest causes of maternal death in South Africa during 2017 – 2019 triennium responsible for 60.6% of the deaths were non-pregnancy related infections (such as Human Immunodeficiency Syndrome [HIV] and tuberculosis [TB]), obstetric hemorrhages and hypertensive disorders of pregnancy and they account for 26.0%, 17.8% and 16.8% respectively.[8] Given that COVID-19 is under the category of non-pregnancy related infections,

one wonders if COVID-19 will not increase the number of maternal deaths in this sub-category in the 2020 – 2022 triennial report. Furthermore, medical and surgical diseases, and pregnancy-related sepsis contributed 12.6% and 9.6% respectively to the maternal deaths in 2017 – 2019 triennium.[14] Among other important cause of maternal deaths reported in the 2017 – 2019 triennium was suicide which has never been documented in the previous Saving Mothers Reports. This is not surprising giving that in low- and middle-income countries (LMICs), several life stressors increase suicidal behaviors and many pregnant women in these settings are at risk of mental illnesses such as postpartum psychosis.[15] Rulisa et al, (2021) in their study on causes of maternal mortality in Rwanda found that the most common causes were sepsis (50%), hemorrhage (19%) and hypertensive disorders (15%) with pre-eclampsia accounting for 13% of the latter.[16] In addition., Samantha et al, (2021) found that among pregnant women in SA who were hospitalized due to COVID-19, maternal mortality was highest in those admitted primarily due to SARS CoV-2 infection unlike for other indications. In the same study, tuberculosis (and not HIV nor other diseases) was the only co-morbidity associated with the hospital admission.[17]

The majority of the maternal deaths (96.3%) in South Africa occur in the health care facilities: Community Health Clinics (CHCs) 2.9%, District Hospitals (DH) 25.3%, and regional hospitals (RH) 33.6%. The proportion of maternal deaths in the tertiary hospitals is 34.5% and most of these deaths (75%) are from women referral from the regional hospitals and CHCs. The high number of maternal mortality in the tertiary hospital is due to a combination of cases referred in poor conditions from the lower levels of care.[8]

In 2014 – 2016 triennium in South Africa, due to a decline in the maternal deaths from non-pregnancy related infections, there was an associated 15% – 36% decrease in the number of

maternal deaths in all provinces except the North West Province.[10] The reason for the non-decline in North West Province was the high number of non-pregnancy related infections (33.47%) compare to other provinces where the numbers of HIV and TB infections decreased significantly. However, in the 2017 – 2019 triennium the numbers of maternal deaths and those attributable to HIV and TB in the North West Province have declined. According to the Saving Mothers Report, the institutional maternal mortality ratio in South Africa during the 2017 - 2019 triennial was 113.8 per 100 000 total live births; and same document shows that the figure for North West Province in the third quarter of 2020 was 113.38 per 100 000 total live births.[8]

1.4.3 Avoidable factors associated with maternal deaths in South Africa

Approximately 62% of maternal deaths in South Africa are preventable/avoidable.[10] The avoidable factors associated with the maternal deaths in South Africa are usually divided into patient-related, healthcare worker-related and administrative-related factors. The commonest healthcare worker-related avoidable factors are poor clinical assessment, inability to recognize problems at CHCs and DHs and failure to follow standard protocol at all levels of health care facilities. Additionally, early discharge of patients from the hospitals without follow-up care is another healthcare worker-related avoidable factor.[8] The most common administrative-related avoidable factors are lack of appropriately trained staff; and 20.5% and 13.7% of the maternal deaths are related to lack of properly trained doctors and nurses respectively.[8] Another administrative-related avoidable factor is the delay in inter-facility transportation from the CHCs to DHs and RHs.[8]

1.4.4 Contribution of COVID-19 to maternal death

As a result of the physiological changes in pregnancy, pregnant women with COVID-19 are susceptible to developing severe illness especially in the third trimester.[18] SARS-CoV-2

triggers immune mediated disorder that causes multi-organ damage including the placental injury.[19] This is primarily related to inflammation and more often due to immune-thrombosis resulting in a wide spectrum of placental-related complications such as pre-eclampsia and thromboembolic disorders.[19] Other mechanisms such as complement activations, release of pro-inflammatory cytokines, antigen-antibody abnormal response, prothrombotic phenomena and endothelial-vascular dysregulation have been implicated in the immune mediated severe forms of COVID-19 in pregnancy.[19] Therefore, the pathogenesis of SARS-CoV-2 in conjunction with the physiological changes in pregnancy can dramatically increase the severity of the disease and contribute to death particularly when there is inadequate patient management.[8]

Recently, a systematic review and meta-analysis showed that pregnant women and their neonates in comparison to the general population with no comorbidities are vulnerable to COVID-19 complications with the overall risk of adverse pregnancy outcomes being higher in LMIC compared to higher-income countries (HIC); with an overall odds ratio (OR) of 2.4 although maternal death had an OR of 7.8 while neonatal deaths showed an OR of 3.7.[20] While COVID-19 is often associated with preterm birth due to iatrogenic delivery to facilitate maternal care, Chae S Y et al., did not find any significant differences in the frequency of preterm birth between women with and without COVID-19: standardized difference = 0.032 (19). Of note, the vertical transmission of SARS-CoV-2 is possible but very rare.[21]

Evidence suggest that maternal mortality increased up to 30% during the COVID-19 lockdown period (between March and September 2020) in comparison with the same period in 2019 [18]. This increase was not only due to the severity of COVID-19 disease in pregnancy but also to indirect effects of COVID-19 on maternal care services.[15] For instance, prioritization of COVID-19 services delayed and compromised other services.[1] Additionally, there was an

increased risk of death in the postpartum period especially for women aged 35 years and above with co-morbidities such as diabetes and hypertension.[22]

1.4.5 Predictors of maternal death in South Africa

There is paucity of data on predictors of maternal death in South Africa. In Ghana, Sumankuuru et al. (2017) showed that intrapartum and post-partum hemorrhages in women aged between 20 - 29 years might be one of the predictors of maternal death. In the same study, women who used herbal medicines during pregnancy were at increased risk of maternal death.[23] There could be similar situation in South Africa where obstetric hemorrhages are among the three leading causes of maternal mortality.[8, 10]

1.5 Aim

To determine the maternal mortality ratio, causes and avoidable factors associated with maternal deaths in K/T hospital before and during the COVID-19 pandemic over a 4-year period (1 March 2018 – 28 February 2022) and to make recommendations that will inform the ongoing strategies on how to decrease the maternal mortality in Klerksdorp and Northwest Province.

1.6 Objectives

1. To describe socio-demographic profile of the women who died during pregnancy or postpartum period during the period under study.
2. To compare the maternal morality ratio before and during the COVID-19 era.
3. To determine the causes and avoidable factors related to the maternal deaths.

2.0 METHODS

2.1 Study design and period of study

This will be a retrospective cross-sectional study. A retrospective chart review of all in-hospital maternal deaths that occurred from 1 March 2018 to 28 February 2020 (two years before COVID-19 was diagnosed in South Africa) and from 1 March 2020 to 28 February 2022 (two years during the COVID-19 pandemic) will be reviewed.

2.2 Study setting

The study will be conducted in K/T hospital complex in the Kenneth Kaunda health district, North West Province, South Africa. Klerksdorp/Tshepong hospital complex comprises of two healthcare facilities viz Klerksdorp Hospital in Klerksdorp town and Tshepong Hospital in Jouberton, one of the Klerksdorp townships. These two hospitals function as a complex and are tertiary healthcare facilities. The department of Obstetrics and Gynecology is located in Klerksdorp Hospital and has a birth rate of approximately 450 deliveries per month. It receives referral from the district and provincial hospitals as well as the primary healthcare clinics in the Kenneth Kaunda health district as well as other health districts in North West Province. In the study setting, an approximately 20 maternal deaths per annum usually occur before the COVID-19 pandemic.

2.3 Study population and sampling

The study population are women who demised in K/T hospitals complex that meet the definition of maternal death/mortality. Maternal mortality is the demise of any woman during the period of pregnancy (irrespective of the weeks of gestational age and location of the pregnancy) or within 42 days following childbirth as a result of causes related or exaggerated by pregnancy but excluding accidental causes.[11] A convenient sample method will be adopted,

and all the in-hospital maternal deaths that occurred in the K/T hospital complex during the period under review (two years before and two years after COVID-19 was diagnosed in South Africa) will be included as the sample.

2.3.1 Inclusion criteria

- All pregnant women and those in the puerperium (within 42 days of childbirth) who demised in the K/T hospital complex.

2.3.2 Exclusion criteria

- Maternal deaths that occurred outside K/T hospital complex.
- Pregnant and postnatal women who died following accidental causes.

2.4 Data collection

The admission and discharge registers in the wards in the Obstetrics and Gynecology Department in K/T hospital complex will be reviewed to identify the maternal deaths and childbirths that occurred in the hospital during the two-year period under review. Additionally, the list of all in-hospital maternal deaths in K/T hospital complex that is kept in the Obstetrics and Gynecology Department in the same hospital will be reviewed to cross-check the number of maternal deaths that occurred in the hospital. The consolidated list of all the maternal death (including the patients' names and hospital numbers) will be used to retrieve the files of the deceased women from the records department of the hospital; and each file will be reviewed for the purposes of data collection. Furthermore, the summary (where available) of the maternal deaths (that occurred during the period under review) which were reported to the NCCEMD according to the South African guidelines [13] will be reviewed for the purposes of data collection. A data collection sheet (Appendix I) will be used to record the data of each woman. The data collection will be performed by the principal investigator who has experience in Obstetrics and Gynecology including analysis of maternal deaths. However, the research

supervisors will offer expert advice during data collection. The following data will be collected using the data collection sheet: socio-demographic profile, chronic illnesses, previous pregnancy, index pregnancy, maternal death, and avoidable factors associated with the maternal deaths. The avoidable/modifiable factors listed in the data collection sheet are contained in the (a) maternal death notification form approved by the NCCEMD in South Africa; and (b) previous literature from studies performed in South African hospitals similar to the index study setting.[24] Figure 1 is a flow diagram illustrating the data collection processes.

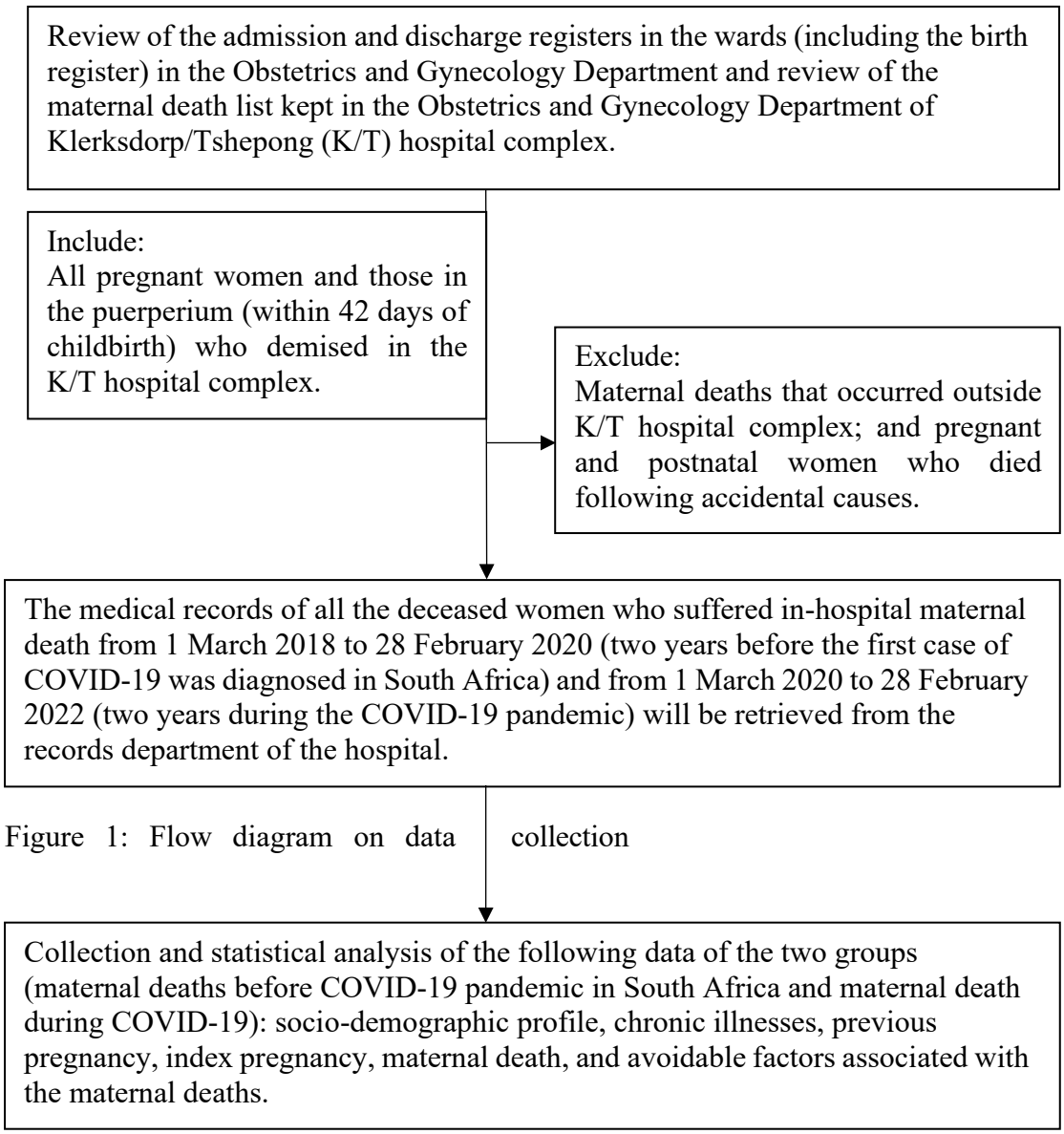


Figure 1: Flow diagram on data collection

2.5 Limitations

The following limitations have been noted and measures to mitigate their effects given due consideration.

1. Given that the study is a retrospective study, there may be cases of missing data or hospital file. However, for the fact that maternal deaths in South Africa are usually discussed soon after its occurrence, adequate data would be available for collection. Moreover, missing files of women who suffered maternal deaths are less likely to occur because these files are carefully safeguarded by the hospital management. Furthermore, missing data will be reported and excluded from data analysis.
2. Bias may occur during the assessment of avoidable factors given that the principal investigator worked in the study setting as a medical officer. Nonetheless, bias is unlikely because the index study is not a medico-legal audit, only summary of the data (rather than data of an individual patient) will be presented, and the final report of this research will not contain any patient identifier. Therefore, collection of data will not be compromised.

3.0 STATISTICS

3.1 Sample size

All the in-hospital maternal deaths that occurred in the K/T hospital complex two years before COVID-19 was diagnosed in South Africa and two years during the COVID-19 pandemic will be the sample.

3.3 Statistical analysis of data

Data will be captured using Microsoft excel and imported into SPSS version 27.0 (IBM, Armonk, NY, USA) for analysis. Categorical variables will be presented as frequencies and

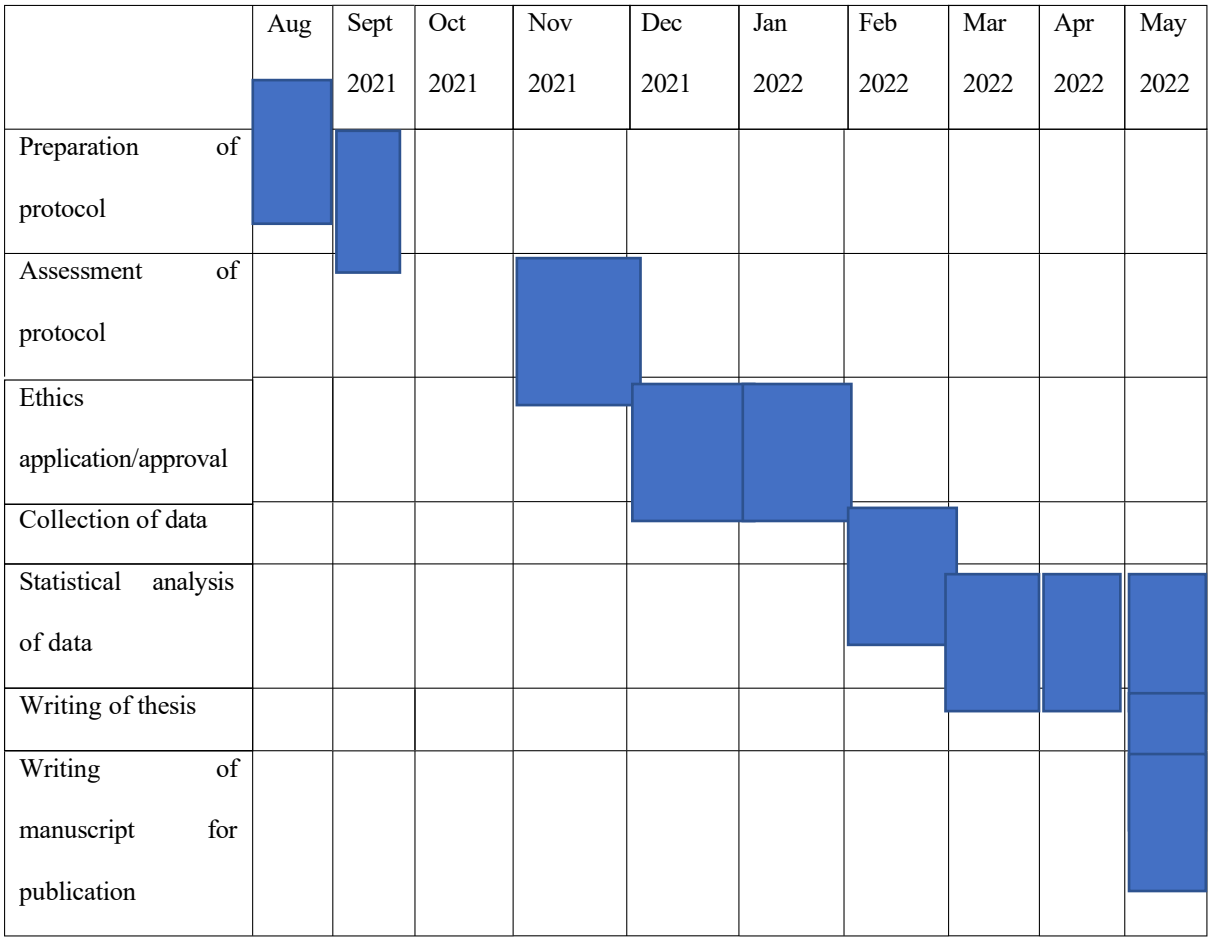
percentages. Numerical variables will be summarized as mean with standard deviation (for normally distributed data) and median with interquartile range (for skewed data). The comparison between the number of maternal deaths caused by a specific medical condition across the two periods (before and during COVID-19) will be performed using Chi-Square test and Fisher Exact test as appropriate. Socio-demographic and clinical characteristics of the deceased will also be compared across the two study periods. Similarly, factors related to the maternal deaths will be compared across the two periods. Normally distributed continuous variables will be compared using Student's t-test while non-normally distributed continuous variables will be compared using Mann-Whitney U test. A *p*-value ≤5 will be considered significant.

The maternal mortality ratio (MMR) will be calculated by dividing the number of maternal deaths during a specified period by the total live births during the same period multiplied by 100 000. The annual percent change will be calculated to determine the change in MMR. The monthly (or annual) MMR will be plotted to describe the trends. MMR due to COVID-19 will be calculated by dividing number of COVID-19 maternal deaths by the number of total live births from COVID-19 positive mothers multiplied by 100 000.

4.0 ETHICS

Permission to perform the study will be obtained from K/T hospital Chief Executive Officer and the head of obstetrics and gynecology department at the hospital. Approval from the University of Witwatersrand Human Research Ethics Committee (WHREC) will be obtained before the inception of the study. The data collection sheet will be anonymized. The collected data will be stored in cupboard with an access key. No patient identifier will be included in the report of the study.

5.0 TIME LINE



6.0 BUDGET

The following is the estimated cost of the study:

Item	Estimated cost (Rands)
Telephone calls concerning the research	R500
Internet services	R500
Photocopy and printing of research documents	R1500
Binding of thesis	R600
Presentation of the research findings at a scientific conference	R7000
Total	R10100

7.0 REFERENCES

1. Ngene NC, Onyia CO, Chigbu CO, Chauke L. Delay in managing benign gynaecological conditions in women of reproductive age during the COVID-19 pandemic in low-and middle-income countries. Case Rep Womens Health 2021;31:e00314. doi: https://doi.org/10.1016/j.crwh.2021.e00314.
2. Nyasulu J, Pandya H. The effect of corona virus disease 2019 pandemic on the South African health system: A call to maintain essentiel health services. Afr J Prim Health Care Fam Med 2020;12(1):e1-e5. doi: https://doi.org/10.4102/phcfm.v12i1.2480.
3. World Health Organization. WHO Coronavirus (COVID-19) Dashboard 2022. Available from: https://covid19.who.int (accessed 9 January 2022).
4. Ding W, Wang Q, Zhang J. Analysis and prediction of COVID-19 epidemic in south Africa. ISA Trans 2021 January 28; S0019-0578(21)00060-4. doi: https://doi.org/10.1016/j.isatra.2021.01.050. Online ahead of print.
5. Jassat W, Cohen C, Tempia S, et al. Risk factors for COVID-19-related in-hospital mortality in a high HIV and tuberculosis prevalence setting in South Africa. The Lancet HIV 2021;8(9):e554-e567. doi: https://doi.org/10.1016/S2352-3018(21)00151-X.
6. Chmielewska B, Barratt I, Townsend R, et al. Effects of the COVID-19 pandemic on maternal and perinatal outcomes: a systematic review and meta-analysis. Lancet Glob Health 2021;9(6):e759-e772. doi: https://doi.org/10.1016/S2214-109X(21)00079-6.
7. Basu K, Chauke L, Magoro T. Maternal mortality from COVID 19 among South African pregnant women. J Matern Fetal Neonatal Med 2021 March 22;1-3. doi: https://doi.org/10.1080/14767058.2021.1902501. Online ahead of print.
8. National Committee on Confidential Enquiry into Maternal Deaths in South Africa. Saving Mothers and Babies 2017 – 2019: Executive summary Plus Final report on the

effect of the first wave of COVID-19 on use of maternal and reproductive health services and maternal and perinatal deaths in South Africa. Pretoria: National Department of Health. 2020.

9. Makinga PN, Moodley J, Titus MJ. The profile of maternal deaths in a district hospital: a five-year review of maternal deaths from 2006 - 2010. S Afr Fam Pract 2012;54(6):518-524. doi: https://doi.org/10.1080/20786204.2011.10874059.

10. Pattinson RC, editor. Saving mothers report 2014-2016. Pretoria: National Departement of Health. 2017.

11. University College Cork. Definition and classification of Maternal Death. 2021. Available from: https://www.ucc.ie/en/mde/definitionandclassificationofmaternaldeath/ (accessed 3 November 2021).

12. Word Health Organization. Indicator Metadata Registry List. Available from: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4622 (accessed 13 January 2021).

13. Moodley J, Pattinson RC, Fawcus S, Schoon MG, Moran N, Shweni PM, et al. The Confidential Enquiry into Maternal Deaths in South Africa: a case study. BJOG 2014;121(4):53-60. doi: https://doi.org/10.1111/1471-0528.12869.

14. South Africa National Departement of Health . South African Maternal, perinatal, and neonatal health policy. 21 June 2021. Available from: https://www.knowledgehub.org.za/system/files/elibdownloads/2021-06/SA%20MPNH%20Policy%2023-6-2021%20signed%20Web%20View%20v2.pdf (accessed 26 September 2021).

15. Maverick Citizen. Increase of 30% in maternal deaths reported during Covid-19 lockdown. Daily Maverick. Available from:

https://www.dailymaverick.co.za/article/2021-03-08-increase-of-30-in-maternal-deaths-reported-during-covid-19-lockdown/ (accessed 26 September 2021).

16. Rulisa S, Ntihinyurwa P, Ntirushwa D, Olufolabi A. Causes of Maternal Mortality in Rwanda, 2017-2019. Obstet Gynecol 2021;138(4):552-556. doi: https://doi.org/10.1097/AOG.0000000000004534.

17. Budhram S, Vannevel V, et al. Maternal characteristics and pregnancy outcomes of hospitalized pregnant women with SARS-CoV-2 infection in South Africa. Int J Gynaecol Obstet 2021;156(1):455-465. doi: https://doi.org/10.1002/ijgo.14027.

18. Hunter M, Moodley J, Moran N. Perspectives on COVID-19 vaccination for pregnant women in South Africa. Afr J Prim Health Care Fam Med 2021;13(1):e1-e3. doi: https://doi.org/10.4102/phcfm.v13i1.2998.

19. Ferrer-Oliveras R, Mendoza MS, et al. Immunological and physiopathological approach of COVID-19 in pregnancy. Arch Gynecol Obstet 2021;304(1):39-57. doi: https://doi.org/10.1007/s00404-021-06061-3.

20. Gajbhiye RK, Sawant MS, Kuppusamy P, Surve S, et al. Differential impact of COVID-19 in pregnant women from high-income countries and low- to middle-income countries: A systematic review and meta-analysis. Int J Gynaecol Obstet 2021;155(1):48-56. doi: https://doi.org/10.1002/ijgo.13793.

21. Chae SY, Bhattacharyya A, Rosa Mendoza R. COVID-19 in Pregnancy: A Current Review of Global Cases. Obstet Gynecol Surv 2021;76(8):504-513. doi: https://doi.org/10.1097/OGX.0000000000000925

22. Knobel R, Takemoto MLS, Nakamura-Pereira M, Menezes MO, et al. COVID-19-related deaths among women of reproductive age in Brazil: The burden of postpartum. Int J Gynaecol Obstet 2021;155(1):101-109. doi: https://doi.org/10.1002/ijgo.13811.

23. Sumankuuro J, Wulifan JK, Angko W, Crockett J, Derbile EK, Ganle JK. Predictors of maternal mortality in Ghana: evidence from the 2017 GMHS Verbal Autopsy data. Int J Health Plann Manage 2020;35(6):1512-1531. doi: https://doi.org/10.1002/hpm.3054.

24. Ngene NC, Moodly RP, Von Rahden PN. Avoidable factors associated with pregnant and postpartum patients admitted to two intensive care units in South Africa. S Afr J Obstet Gynaecol 2016;22(1):8-12. Available from: https://hdl.handle.net/10520/EJC195912 (accessed 13 January 2021).

APPENDIX 2: DATA COLLECTION SHEET

A. Socio-demography profile

1. Patient code ……
2. Age (years): ……....
3. Residential district: 1. kenneth Kaunda (KK) 2. Outside Kenneth Kaunda district in North West 3. Outside North West.
4. Marital status: 1. Single 2. Married 3. Divorced 4. Single but lives with partner
5. Occupation: 1. Employed 2. Unemployed 3. Unemployed and lives on grant
6. Race: 1. Black 2. Asian 3. Caucasian 4. Coloured 5. Others
7. Smokes cigarette? 1. Yes 2. No
8. Uses other social substances: 1. Yes 2. No
9. Name of district where the patient live: ……..
10. Was patient referred to Klerksdorp/Tshepong Hospital: 1. Yes 2. No
11. Name of referring hospital, if applicable: …….

B. Chronic medical and surgical conditions

12. Chronic medical/surgical condition: 1. Yes 2. No
13. Name of chronic medical/surgical condition: 1. HIV positive 2. Chronic hypertension 3. Pre-gestational diabetes 4. Epilepsy 5. Others (specify) …….
14. If HIV positive, was on antiretroviral therapy? 1. Yes 2.No 3. Unknown
15. If HIV positive, CD4 count assessed in pregnancy: 1. Yes 2. No 3. Unknown
16. CD4 count (cells/µl) if HIV positive…….
17. If CD4 <200, was the patient on Bactrim? 1. Yes 2. No 3. Unknown
18. If HIV positive, viral load assessed in pregnancy: 1. Yes 2. No 3. Unknown

19. Viral load (copies/ml) if HIV positive…….

20. If Viral load <100, what was Cryptococcal Latex Agglutination Test (CLAT)? 1. CLAT positive 2. CLAT negative 3. Unknown

C. Previous pregnancies

21. Number of previous pregnancies including the index pregnancy: …….

22. Number of pregnancies beyond 24 weeks or babies weighed ≥500 g at birth….

23. Number of previous choice termination of pregnancy: …….

24. Previous caesarean delivery: 1. Yes 2. No 3. Primigravida

25. Complications in previous pregnancies: 1. Yes 2. No

26. Type of complication in the previous pregnancy: 1. Gestational hypertension 2. Preeclampsia 3. Gestational diabetes 4. Others (specify)…….

D. Index pregnancy

27. Attended antenatal clinic? 1. Yes 2. No 3. Unspecified

28. Gestational age (weeks) at first antenatal clinic visit: 1. Less than 20 weeks 2. Above 20 weeks

29. Had anemia during pregnancy (Hemoglobin < 11 g/dl)? 1. Yes 2. No

30. Rapid Plasma Reagin (RPR) result: 1. non-reactive 2. Reactive 3. Unknown

31. Weight (Kg) at booking…….

32. Mid-upper arm circumference (cm) at first antenatal clinic visit: ……

33. Height (m): ……

34. Had COVID-19 disease in the index pregnancy? 1. Yes 2. No

35. Antenatal complications present? 1. Yes 2. No

36. What were the antenatal complications (if applicable): ……

37. Management of antenatal complications met expectation:

1. Yes 2. No 3. Sometimes

Specify……

……

38. Route of delivery: 1. Vaginal 2. Caesarean 3. Undelivered

39. Labour (if vaginal delivery): 1. Spontaneous 2. Induced

40. Indication for caesarean delivery (if applicable) …….

41. Estimated blood loss (mls) during delivery ……..

42. APGAR score…….…….

43. Birth weight (gram)…….

44. Gender of baby: 1. Female 2. Male 3. Indeterminate

45. Intrapartum complications present? 1. Yes 2. No

46. What were the intrapartum complications (if yes): ……

47. Management of intrapartum complications were appropriate:

1. Yes 2.No 3. Sometimes

Specify……

…….

48. Postpartum complications present? 1. Yes 2. No

49. What were the postpartum complications (if yes): ……

50. Management of intrapartum complications were appropriate: 1. Yes 2.No

3. Sometimes

Specify……

…….

51. Admitted in obstetric high-care unit: 1. Yes 2. No

52. Main indication for obstetric high-care admission: ……

53. Admitted in the Intensive Care Unit (ICU): 1. Yes 2.No

54. Main indication for ICU admission: …….

55. Patient had mechanical ventilation: 1. Yes 2. No

E. Maternal death

56. Period of death: 1. Before COVID-19 in South Africa 2. During COVID-19 era

57. Date of hospital admission …..

58. Time of hospital admission ……

59. Date of death…….

60. Time of death……

61. Unit where patient died: 1. ICU 2. Obstetric high-care 3. Ward 4. Casualty 5. During transfer from Tshepong Hospital to Klerksdorp Hospital or vice versa

62. Primary cause of maternal death: ……

63. Other diagnoses at the time of death……

64. Final cause of maternal death: 1. Cardiopulmonary arrest 2. Cardiac arrest 3.Respiratory failure 3. Renal failure 4. Liver failure 5. Hypovolemia 6. Septic shock 7. Multiple organ failure

F. **Avoidable factors related to management of the clinical condition**

65. Avoidable factor: 1. Present 2. Absent

66. Category of clinical condition that has avoidable factor in its management (choose more than one category if applicable): 1. Non-pregnancy related infection 2. Hypertensive disorders 3. Obstetric haemorrhage 4. Puerperal sepsis 5. Ectopic pregnancy 6. Medical and surgical conditions 6. Others (specify): ……

67. Avoidable factors related to non-pregnancy related infection (describe/list): …….

68. Avoidable factors related to hypertension (describe/list):

…….

69. Avoidable factors related to haemorrhage (describe/list):

…….

70. Avoidable factors related to puerperal sepsis (describe/list):

…….

71. Avoidable factors related to ectopic pregnancy (describe/list):

…….

72. Avoidable factors related to medical and surgical conditions (describe/list):

…….

73. Avoidable factors related to ……. (Specify condition) (describe):

…….

G. Patient-related avoidable factors associated with the maternal death

74. Patient-related avoidable factor:	1. Present	2. Absent
75. Had no antenatal care	1. Yes	2 No
76. Defaulted antenatal clinic	1.Yes	2. No
77. Commenced antenatal care after 20 weeks' gestation	1.Yes	2 No
78. Declined medical treatment	1.Yes	2 No
79. Delayed to seek medical treatment	1.Yes	2 No
80. Unsupervised delivery at home	1.Yes	2 No
81. Unsafe abortion	1.Yes	2 No
82. Use of herbal concoction	1.Yes	2 No
83. Others (specify) ……	1. Yes	2. No

H. Healthcare worker-related avoidable factors associated with the maternal death

84. Healthcare worker-related avoidable factor:	1. Present	2. Absent
85. Lack of expertise, training or education?	1. Yes	2. No
86. Lack of human resources	1. Yes	2. No
87. Delay in referral?	1. Yes	2. No
88. Wrong diagnosis	1. Yes	2. No
89. Wrong treatment	1. Yes	2. No
90. Delay in other appropriate action?	1. Yes	2. No
91. Others (Specify): …….	1. Yes	2. No

I. Administrative –related avoidable factors associated with the maternal death

92. Administrative-related avoidable factor:	1. Present	2. Absent
93. Delayed or lack of transportation	1. Yes	2. No
94. Lack of bed in the ward	1. Yes	2. No
95. Delay or lack of ICU or high-care	1. Yes	2. No
96. Lack of trained medical staff	1. Yes	2. No
97. Lack of blood or blood products	1. Yes	2. No
98. Lack of equipment	1. Yes	2. No
99. Lack of medicine	1. Yes	2. No
100. Communication breakdown	1. Yes	2. No
101. Others (specify): …….	1. Yes	2. No

APPENDIX 3: HREC CLEARANCE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr Ongombe Lunda

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M220359

NAME: (Principal Investigator)	Dr Ongombe Lunda
DEPARTMENT:	Obstetrics and Gynaecology Klerksdorp Hospital
PROJECT TITLE:	Maternal deaths before and during COV-19 pandemic: causes and avoidable factors in a tertiary hospital in South Africa
DATE CONSIDERED:	25/03/2022
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr NC Ngene, Prof L Chauke and Dr G Deaf
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	05/05/2022

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the Third Floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions.Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.** The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in **March** and will therefore be due in the month of **March** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

10/05/2022
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX 4: APPROVAL OF TITLE

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

07 February 2022
Person No: 2620318
PAG

Dr O Lunda
8 Graniet Street
Wilkoppies
2571
South Africa

Dear Dr Ongombe Lunda

Master of Medicine in Obstetrics and Gynaecology: Approval of Title

We have pleasure in advising that your proposal entitled *Maternal deaths before and during covid-19 pandemic: causes and avoidable factors in a tertiary hospital in South Africa* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

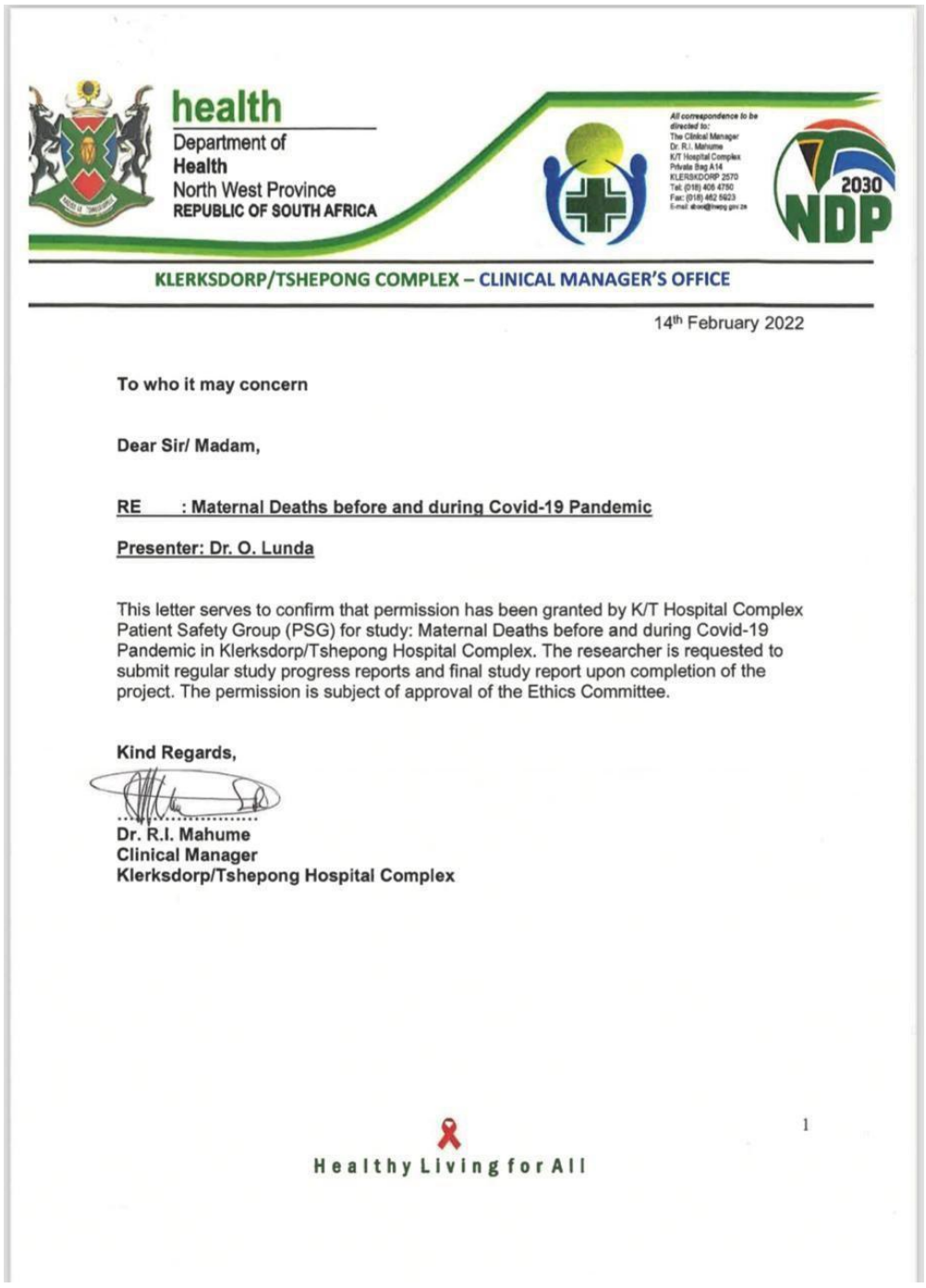
Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Approved
Chairman PSC

100 1922 2022

APPENDIX 5: KLERKSDORP/TSHEPONG HOSPITAL PERMISSION



health
Department of
Health
North West Province
REPUBLIC OF SOUTH AFRICA

All correspondence to be directed to:
The Clinical Manager
Dr. R.I. Mahume
K/T Hospital Complex
Private Bag A14
KLERKSDORP 2570
Tel. (018) 406 4790
Fax: (018) 462 5623
E-mail: dr.ovo@nwpg.gov.za

2030 NDP

KLERKSDORP/TSHEPONG COMPLEX – CLINICAL MANAGER'S OFFICE

14th February 2022

To who it may concern

Dear Sir/ Madam,

RE : Maternal Deaths before and during Covid-19 Pandemic

Presenter: Dr. O. Lunda

This letter serves to confirm that permission has been granted by K/T Hospital Complex Patient Safety Group (PSG) for study: Maternal Deaths before and during Covid-19 Pandemic in Klerksdorp/Tshepong Hospital Complex. The researcher is requested to submit regular study progress reports and final study report upon completion of the project. The permission is subject of approval of the Ethics Committee.

Kind Regards,

Dr. R.I. Mahume
Clinical Manager
Klerksdorp/Tshepong Hospital Complex

1

Healthy Living for All

PLOS ONE

APPENDIX 6: PLOS ONE MANUSCRIPT BODY FORMATTING GUIDELINES

Abstract

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Introduction

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Materials and methods

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Vestibulum adipiscing urna ut lectus gravida, vitae (Fig 1) interdum. Donec tincidunt porta sem nec hendrerit. Vestibulum nec pharetra quam, vitae convallis nunc. Mauris in mattis sapien. Fusce sodales vulputate auctor. Nam sit amet nulla lacus a, Figs 1 and 2 ultrices tellus. Integer rutrum aliquet sapien, eu fermentum magna pellentesque vitae.

Fig 1. This is the Fig 1 Title. This is the Fig 1 legend.

Fig 2. This is the Fig 2 Title. This is the Fig 2 legend.

Level 1 Heading

- Use Level 1 heading for all major sections (Abstract, Introduction, Materials and methods, Results, Discussion, etc.).
- Bold type, 18pt font.
- Only use italics and text formatting where needed (e.g. genus and species names, genes, etc.).
- Headings should be written in sentence case (capitalize only the first word of the heading, the first word of the subheading, and any proper nouns and genus names).

NOTE: Do not cite figures, tables, supporting information, or references in the Abstract.

Figure Citations

- Cite figures as "Fig 1", "Fig 2", etc.
- Cite figures and tables in order.
- Do not cite "Fig 2" before "Fig 1".
- Cite multiple figures as "Figs 1 and 2", "Figs 1-3", etc.

Figure Captions

- Each figure caption should appear directly after the paragraph in which they are first cited.
- Do not include tables within captions.
- Use bold type for the figure titles.

File Naming for Figures

- Figure files should be saved as "Fig1.tif", "Fig2.eps", etc.
- Acceptable file formats for figures are ".tif", ".tiff", and ".eps"
- Figures should be uploaded separately as individual files.
- PLOS ONE guidelines for figures can be found here: http://journals.plos.org/plosone/s/figures

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$$p^2 + 2pq + q^2 = 1 \quad (1)$$

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Genotyping

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Whole genome RFLP analysis

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NOTE: This document is presented in single-space paragraph format for ease of use. Please submit your manuscript in double-space paragraph format.

Display/Numbered Equation

- Format display equations in Mathtype or Equation Tools.
- Do not use Graphic Objects.

Inline Equation

- Format in regular text or as an inline equation in Mathtype or Equation Tools.
- Do not use Symbol Font.
- Do not use Graphic Objects.

Level 2 Heading

- Use Level 2 headings for sub-sections of major sections.
- Bold type, 16pt font.
- Only use italics and text formatting where needed.
- Use sentence case.

Level 3 heading

- Use Level 3 headings for sub-sections within Level 2 headings.
- Bold type, 14pt font.
- Only use italics and text formatting where needed.
- Use sentence case.

Results and discussion

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Vestibulum adipiscing urna ut lectus gravida, et bland Table 1 Donec tincidunt porta sem nec hendrerit. Vestibulum nec pharetra quam, vitae convalli. Fido nemo.

Table 1. This is the Table 1 Title.

	Chemical W	Chemical X	Chemical Y	Chemical Z
Chemical 1	Reaction 1W	Reaction 1X	Reaction 1Y	Reaction 1Z
Chemical 2	Reaction 2W	Reaction 2X	Reaction 2Y	Reaction 2Z
Chemical 3	Reaction 3W[a]	Reaction 3X	Reaction 3Y[b]	Reaction 3Z
Chemical 4	Reaction 4W	Reaction 4X	Reaction 4Y	Reaction 4Z
Chemical 5	Reaction 5W	Reaction 5X	Reaction 5Y	Reaction 5Z

This is the Table 1 legend.

[a]Table footnotes belong here.

[b]Footnotes should have corresponding symbols in the table.

Tables and Table Citations

- Tables should be cited as "Table 1", "Table 2", etc.
- Cite multiple tables as "Tables 1 and 2", "Tables 1-3", etc.
- Tables should be included directly after the paragraph in which they are first cited.
- Tables must be cell-based in Microsoft Word or embedded with Microsoft Excel.
- Do not use empty rows to create spacing.
- Do not include graphic objects, images, or colored text.
- See PLOS ONE Table Guidelines for more complete instructions: http://journals.plos.org/plosone/s/tables

Conclusions

Lorem ipsum dolor sit amet, consectetur adipiscing [1-5]. Vestibulum adipiscing urna ut lectus gravida, vitae blandit tortor interdum. Donec tincidunt porta sem nec hendrerit. Vestibulum nec pharetra quam, vitae convallis nunc. Mauris in mattis sapien. Fusce sodales vulputate auctor S1 Fig. Dolor sit amet S1 and S2 Tables.

Reference Citations

- Cite references in brackets (for example, "[1]" or "[2-5]" or "[3,7,9]").
- References must be cited in order at first mention.

Supporting Information Citations

- Format Supporting Information Citations as "S1 Fig", "S1 Table", etc.
- Cite multiple files as "S1 and S2 Figs", "S1-S3 Figs", etc.
- It is not required to cite each Supporting Information file.
- Supporting information should be uploaded separately as individual files.

Acknowledgments

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Acknowledgments

- Do not include funding or competing interests information in Acknowledgments.

References

1. Doe J, Data A, van Stats J, Testperson M, Ribosome D Jr, McBio GHT, et al. This is the article title. PLoS ONE. 2017;12(12):e00000. doi: 10.1371/journal.pone.0000000
2. Doe J, Data A, van Stats J, Testperson M, Ribosome D Jr, McBio GHT, et al. Bunny dynamics in cartoon landscapes. PLoS ONE. Forthcoming 2017.

References

- References should be listed after the main text, before the supporting information.
- References with more than six authors should list the first six author names, followed by "et al."
- Please see the PLOS ONE guidelines for References here: http://journals.plos.org/plosone/s/submission-guidelines#loc-references

Supporting information

S1 Fig. This is the S1 Fig Title. This is the S1 Fig legend.

S2 Fig. This is the S2 Fig Title. This is the S2 Fig legend.

S1 Table. This is the S1 Table Title. This is the S1 Table legend.

S2 Table. This is the S2 Table Title. This is the S2 Table legend.

S1 File. This is the S1 File Title. This is the S1 File legend.

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- Use a Level 1 heading.
- Use bold type for the titles.
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APPENDIX 7: TURNITIN REPORT

Manuscript submitted with figures and supplementary table - 1 Jan 2025 (2).docx

by Ongombe Lunda

Submission date: 07-Feb-2025 09:59AM (UTC+0200)

Submission ID: 2581961314

File name: Manuscript_submitted_with_figures_and_supplementary_table_-_1_Jan_2025_282_29.docx (138.62K)

Word count: 8004

Character count: 45289

Abstract

Aim: To determine the institutional maternal mortality ratio (iMMR) and avoidable factors (AVFs) before and during the COVID-19 pandemic (COVID-19-P) in a tertiary hospital in South Africa.

Methods: This was a retrospective cross-sectional study. We reviewed medical records to compare iMMR and associated AVFs two years before (March 2018 - February 2020) and two years during (March 2020 - February 2022) COVID-19-P.

Results: Fifty-eight maternal deaths (MDs) were recorded but available data was 57 (35 before and 22 during COVID-19-P). The highest iMMR per 100,000 live births over a 12-month period was 329.1 before and 201.8 during COVID-19-P. The mean ages were 31.0 ± 6.9 and 31 ± 6.2 years, p=0.822 before and during COVID-19-P, respectively. During COVID-19-P, 40.9% (9/22) were diagnosed with COVID-19. Before and during the pandemic, 71.4% (25/35) and 68.2% (15/22) p=1.0 were admitted into an intensive care unit (ICU), respectively, with corresponding 74.3% (26/35) and 50% (11/22), p=0.026 requiring mechanical ventilation. There was a significant difference in the primary causes of death (p=0.009) for the two periods, with preeclampsia with severe features (22.9%, 8/35) being the leading cause before COVID-19-P compared to COVID-19 (31.8%, 7/22) during the pandemic. AVFs related to healthcare professionals were the most common occurring in 22/35 and 12/22 of the deceased before and during COVID-19-P, respectively. Before COVID-19-P, the most frequent patient-, healthcare professional-, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care bed spaces, respectively. During COVID-19-P, the most common patient-, healthcare worker- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability of ICU/high care bed spaces, respectively.

Conclusion: iMMR was lower during than before COVID-19-P. AVFs related to healthcare professionals were the most common.

Keywords: Avoidable factor, COVID-19, maternal deaths, maternal mortality ratio, Severe Acute Respiratory Syndrome Coronavirus 2

1. Introduction

The socioeconomic challenges and adverse health outcomes associated with the coronavirus disease 2019 (COVID-19) pandemic have been devastating to many individuals, families, and communities. However, evidence-based interventions such as vaccination and non-pharmacological interventions including regular hand washing, as well as attainment of herd immunity, have largely halted the scourge of the disease. COVID-19 was first reported in China in the city of Wuhan on 8 December 2019 [1]. It is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). On 11 March 2020, the World Health Organization (WHO) declared the disease a pandemic [1]. The disease is highly infectious and in Sub-Saharan Africa had a case fatality rate of 3.4% [2]. As of 23 December 2024, it had resulted in 7.1 million deaths worldwide [3]. In South Africa, the first case was reported in the KwaZulu-Natal province on 6 March 2020. The infection rapidly spread to other provinces with the national cumulative confirmed cases per million people increasing to 3 398.46 in six months (as of 8 September 2020) and to 58 068.32 in two years (as of 6 February 2022). By 6 June 2022, the figure had become 63 596.97 per million people and the gradient plateaued [4]. To place this in context, South Africa had a mid-year population of approximately 60 million in 2021 [5]. By 20 June 2022, all the COVID-19 restrictions in South Africa had been lifted [6]. Following a declining trend in the number of deaths and hospitalizations from the disease globally, WHO declared on 5 May 2023 that COVID-19 was no longer a public health emergency of international concern [7]. Some survivors of the disease, however, are still battling to cope with

the debilitating effects of long COVID-19. The pandemic disrupted activities of daily living including the usual routines in the health sector and, as a result, healthcare resources had to be redistributed to contain the pandemic [8]. Furthermore, COVID-19 deaths preferentially affected vulnerable groups such as persons with comorbidity (including hypertension and diabetes) and those with immunosuppression [9]. Consequentially, many maternal deaths (MDs) due to COVID-19 occurred globally including in South Africa [10].

During the pandemic, pregnant women in South Africa with severe COVID-19 were transferred to regional and tertiary hospitals for further management because of the availability of established critical care services at these referral centers. In the context of this referral pattern, the contribution of COVID-19 to MDs in South Africa has not been exhaustively studied. Although data on institutional MDs in South Africa are collated and published every three years in the Saving Mothers Report [10], evidence suggests that the most common causes of and trends in MDs at the national level (based on the consolidated data from various healthcare facilities) may be different from a hospital-specific data review [11]. The 2017–2019 Saving Mothers Report suggests that the national institutional maternal mortality (iMMR) ratio increased during the first wave of the COVID-19 pandemic (COVID-19-P) in South Africa, from 98.8 to 126.1 per 100,000 live births [10]. Whether or not iMMR increased in each maternity unit in South Africa during the COVID-19-P remains uncertain.

The iMMR, causes of MDs, and associated avoidable factors (AVFs) before and during COVID-19-P have not been studied in Klerksdorp/Tshepong (K/T) Hospital, the only tertiary hospital in the North West province of South Africa. The information gained from such research could assist with the identification and implementation of interventions to prevent future MDs and prepare the health system for future pandemics. The aim of this study,

therefore, was to determine the trends in iMMR, causes, and AVFs associated with MDs in a tertiary hospital in the North West province in South Africa over a four-year period (1 March 2018–28 February 2022) comprising two years before and two years during the COVID-19 pandemic.

2. Materials and Methods

2.1 Study design and period

This is a four-year retrospective cross-sectional record review of all in-hospital MDs that occurred before COVID-19-P (1 March 2018–28 February 2020), and during it (1 March 2020–28 February 2022). The study covered the 24-month period immediately before COVID-19 was diagnosed in South Africa in March 2020 and the immediate 24-month period during the COVID-19-P. Data collection from the medical records for research purposes was from 1 June 2022 to 31 December 2022.

2.2 Study setting

The study was conducted in the K/T hospital, which is made up of two healthcare facilities namely Klerksdorp Hospital in Klerksdorp town and Tshepong Hospital in Jouberton township) in Kenneth Kaunda District, North West Province, South Africa. The two public hospitals are tertiary facilities that function as a complex. The Department of Obstetrics and Gynecology is in Klerksdorp Hospital and conducts 480 deliveries per month. It receives referrals from the district and provincial hospitals as well as 16 primary healthcare clinics in the Kenneth Kaunda Health District and other health districts in the North West province. Four of the primary health care clinics function as midwife-led obstetric Units. Of note, the referral patterns to the hospital did not change during the study period, with all patients presenting with

respiratory symptoms suspected to be tuberculosis and those diagnosed with COVID-19 being screened for tuberculosis.

In South Africa, the initial three COVID-19 waves (high rate of SARS-CoV-2 transmission) occurred from April 2020 to September 2021 with the timing of the surges being similar across the provinces in South Africa [12, 13]. There was successive higher positivity of diagnostic test, incidence, and mortality of COVID-19 across the three periods with the ancestral strain, Beta (B.1.351) and Delta (B.1.617.2) variants being responsible for the first, second, and third waves, respectively [12]. From October 2021 to February/March 2022, another wave caused by Omicron (BA.1) occurred although less positivity and mortality were recorded [14]. Following this period, the disease became stable as vaccination and natural infection achieved herd immunity.

2.3 Study population and sample

The study population was MDs in the study setting. The study sample comprised all women who demised in the K/T hospital complex that met the definition of MD during the 4-year study period. This was the eligibility criteria. According to the WHO, maternal mortality is the demise of any woman during the period of pregnancy (irrespective of the weeks of gestational age and location of the pregnancy) or within 42 days following childbirth as a result of causes related to or exaggerated by pregnancy but excluding accidental causes [15].

2.4 Data collection

The admission and discharge ward registers in the Obstetrics and Gynecology Department in the K/T hospital complex together with the departmental list of MDs were used to identify the MDs and childbirths that occurred in the hospital during the four-year period under review.

The files of the listed deceased women were retrieved from the records department of the hospital, and the data collection and review of the clinical records were performed by the principal investigator. Afterwards, the research supervisors discussed the MDs with the principal investigator during plenary meetings. Fig 1 is a flow diagram illustrating the data collection processes and the type of data collected.

Fig 1. Flow diagram on data collection

2.5 Data analysis

Data was analyzed using SPSS version 29 (IBM, Armonk, NY, USA), with Joinpoint Regression Program, version 5.0.2 (National Cancer Institute https://surveillance.cancer.gov/joinpoint/) being used to evaluate the six-monthly percentage change in iMMR. A normality check was performed on numerical data using the skewness-Kurtosis test and visual assessment of the distribution of data in plots and charts including the normal curve on a histogram. Categorical variables were presented as frequencies and percentages. Numerical variables were summarized as mean with standard deviation (for normally distributed data) and median with interquartile range (for skewed data). Descriptive statistics was used to compute the trend in MDs, live births, and iMMR. The iMMR was calculated by dividing the number of MDs during a specified period by the total live births during the same period, multiplied by 100 000. A line graph showing six and 12-monthly trends in iMMR was plotted. The six-monthly point periods show the trend in iMMR and provide eight data points, which exceeds the minimum seven required for jointpoint regression analysis [16]. Numerical variables in the two periods (before and during COVID-19-P) were compared using the student t-test and Mann-Whitney U test for normally distributed data and skewed data, respectively. Categorical data were compared using Pearson's Chi-square distribution test

and the Fisher exact test, as appropriate. Statistical significance was set at $p \leq 0.05$. Missing data were excluded from the calculation of the p-value.

2.6 Ethics

Approval from the University of Witwatersrand Human Research Ethics Committee (Reference M220359) was obtained before the inception of the study. The management of the K/T hospital complex also gave approval. During data collection, the medical records of the individual participants (deceased women) had their identities which were accessible to the principal investigator. However, no information that could identify individual participants was used after data collection (including during data capturing, statistical analysis, or reporting of the study findings).

3. Results

There were 58 MDs during the study period, but the medical record of one woman who demised during COVID-19-P could not be found. She was excluded from the analysis but included in the mortality trends.

3.1 Sociodemographic characteristics

There was no statistical difference between the two study periods in terms of the socio-demographic characteristics of the women (Table 1). All 58 reported MDs were Black African women. There was no marked difference between the mean age (in years) of the two groups: 31.0 ± 6.0 before and 31.1 ± 6.2 during COVID-19-P (p = 0.822). Two MDs occurred among teenagers in the period before COVID-19-P.

Table 1. Sociodemographic characteristics of the women

Variable	Values n (%), mean ± SD			p-value
	Before COVID-19 (March 2018 to February 2019)	During COVID-19 (March 2020 to February 2021)	Total	
Mean age ± SD (years)	31.0 ± 6.90	31.1 ± 6.20	31.0 ± 6.0	0.822[t]
Age (years), n (%)				0.344[f]
≤24	3(8.6)	5(22.7)	8(14.0)	
25 – 34	25(71.4)	12(54.5)	37(64.9)	
≥35	7(20.0)	5(22.7)	12(21.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Residence, n (%)				0.621[f]
Kenneth Kaunda (KK) District	22(62.9)	17(77.3)	39(68.4)	
Outside KK district but in same province	12(34.3)	5(22.7)	17(29.8)	
Outside the province	1(2.9)	0(0.0)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Marital status				0.652[f]
Single	32(91.4)	21(95.5)	53(93.0)	
Married	3(8.6)	1(4.5)	4(7.0)	
Total	35(100.0)	22(100.0)	57(100.0)	
Occupation				1.00[f]
Employed	2(5.7)	2(9.1)	4(7.0)	
Unemployed	33(94.3)	20(90.9)	53(93.0)	
Total	35(100.0)	22(100.0)	57(100.00)	
Race				Constant
Black	35(100.0)	22(100.0)	57(100.0)	-
Total	35(100.0)	22(100.0)	57(100.0)	
Cigarette smoking				0.134[f]
Yes	7(20)	1(4.5)	8(14.0)	
No	28(80)	21(95.5)	49(86)	
Total	35(100.0)	22(100.0)	57(100.0)	
Substance use				0.192[f]
Yes	2(5.7)	4(18.2)	6(10.5)	
No	33(94.3)	18(81.8)	51(89.5)	
Total	35(100.0)	22(100.0)	57(100.0)	
District referred from				0.363[f]
Kenneth Kaunda	24(68.6)	16(72.7)	40(70.2)	
Bojanala	0(0.0)	2(9.1)	2(3.5)	
Ngaka Modiri Molema	4(11.4)	1(4.5)	5(8.8)	
Ruth Segomotsi Mompati	6(17.1%)	3(13.6)	9(15.8)	
Kuruman in Northern Cape	1(2.9)	0(0.0)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: t, student t-test; f, Fisher exact test. The p-value applies only to the comparison between the periods before and during COVID-19)

3.2 Antenatal profile, COVID-19 status, and chronic medical conditions

Table 2 is a summary of the antenatal profile, COVID-19 status, and chronic medical condition of the women. Nearly all (94.7%) had been referred to the study setting. A total of

57.9% (33/57) of the women had antenatal care (18 before and 15 during COVID-19-P, p = 0.056). The median parity of all the women was 3 (Interquartile range [IQR] 2 -4), comprising 3 (2 - 3) before and 3 (2 -4) during COVID-19-P, p =0.299. At booking, 57.9% (33/57) of the women had anemia: 62.7% (22/35) before and 50.0% (11/22) during the pandemic, p = 0.476.

187 Table 2. Antenatal profile, COYID-19 status, and chronic medical conditions

Variable	Values n (%), median [!QR]			p-value
	Before COVJD-19 (March 2018 - February 2019)	During COVJD-19 (March 2020 - February 2021)	Total	
Referral status at the study setting				1.00'
Referred	33(94.3)	21(95.5)	54(94.7)	
Not referred	2(5.7)	1(4.5)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Delay in referral				1.00'
Yes	7(20.0)	4(182)	11(19.3)	
No	28(80.0)	18(81.8)	46(80.7)	
Tota.l	35(100.0)	22(100.0)	57(100.0)	
Refe1Ting institution				0.132'
Clinic in Kennet Kaunda	16(45.7)	10(45.5)	26(45.6)	
Hospital in Kennet Kaunda	1(2.1)	5(22.7)	6(10.5)	
Institution outside Kennet Kaunda in North \Vest Province	11(31.4)	6(27.3)	17(29.8)	
Institution outside North	2(5.7)	0(0.0)	2(3.5)	
Tshepong Hospit:Ll	3(8.6)	0(0.0)	3(5.3)	
Not referred	2((5.7)	1(4.5)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of chronic condition, n (%)				0.810'
HIV	20(57.1)	14(63.6)	34(59.6)	
Chronic Hypertension	1(2.9)	1(4.5)	2(3.5)	
Epilepsy	0	1(4.5)	1(1.8)	
HfV and hypertension	1(2.9)	0	1(1.8)	
Nochronic condition	12(34.3)	6(27.3)	18(31.6)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
HIV antiretroviral therapy (ART)				1.00'
OnART	12(34.3)	7(31.8)	19(33.3)	
Not ART	6(17.1)	3(13.6)	9(25.7)	
HIV negative	14(24.6)	8(36.4)	22(62.8)	
Missing data among HfV women	3(8.6)	4(18.2)	7(12.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
CD4 count (cells/µ!) range and **median, n =26**				0.133'"
Minimum	4	46	4	
Maximum	1484	1067	1484	
Median, IQR	I 16[11.5-378]	331[197- 667]	312 [39 - 459]	

Table 2 (continued)

Variable	Values n (%), median [IQR]			p-value
	Before COVID-19 (March 2018 – February 2019)	During COVID-19 (March 2020 – February 2021)	Total	
CD4 Category (cells/µl)				0.319[f]
<199	9(42.9)	2(14.3)	11(31.4)	
200-499	5(23.8)	5(35.7)	10(28.6)	
≥500	3(14.3)	2(14.3)	5(14.3)	
Missing data	4(19.0)	5(35.7)	9(25.7)	
Total	21(100.0)	14(100.0)	35(100.0)	
Bactrim use if CD4 <200 cells/µl				0.616[f]
Yes	2(9.5)	0(0.00)	2(5.7)	
No	10(47.6)	7(50.0)	17(48.6)	
Unknown	1(4.8)	0(0.00)	1(2.9)	
CD4≥200	8(38.1)	7(50.0)	15(42.9)	
Total	21(100.0)	14(100.0)	35(100.0)	
HIV viral load (copies/ml), range, and median				0.285[m]
Minimum	0	0	0	
Maximum	4697585	1180739	4697585	
Median (IQR)	1787 [45–83010]	16844.5 [1458–171120.8]	4738 [60.5-106274]	
HIV viral load (copies/ml), category				0.261[m]
<200	6(28.6)	2(14.3)	8(22.9)	
≥200 – 99999	7(33.3)	4(28.6)	11(31.4)	
≥100000	2(9.5)	4(28.6)	6(17.1)	
Missing data	6(28.6)	4(28.6)	10(28.6)	
Total	21(100.0)	14(100.0)	35(100.0)	
Previous pregnancy ≥ 24 weeks' gestation				0.141[m]
Minimum	1	1	1	
Maximum	9	6	9	
Median [IQR]	3[2-3]	3[2-4]	3[2-4]	
Previous pregnancy ≥ 24 weeks' gestation				0.299[f]
1	5(14.2)	2(9.1)	7(12.3)	
2 4	27(77.1)	16(72.7)	43(75.3)	
≥5	2(5.7)	4(18.1)	6(10.6)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Previous pregnancy less than 24 weeks' gestation				0.397[m]
Minimum	0	0	0	
Maximum	8	5	8	
Median [IQR]	2[1-2]	2[1-3]	2[1-3]	

193 Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-Value
	Before COVID-19 (March 2018 – February 2019)	During COVID-19 (March 2020 – February 2021)	Total	
Previous pregnancy less than 24 weeks' gestation				0.326[f]
0	4(11.4)	1(4.5)	5(8.8)	
1-2	23(65.7)	13(59.1)	36(63.1)	
≥3	7(20.0)	8(36.4)	15(26.3)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Previous termination of pregnancy				0.652[m]
Minimum	0	0	0	
Maximum	1	1	1	
Median [IQR]	0[0-0]	0[0-0]	0[0-0]	
Previous termination of pregnancy				
0	32(91.4)	20(90.9)	52(91.2)	1.000[f]
1	2(5.7)	2(9.1)	4(7.0)	
Missing data	1(2.9)	0	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Previous caesarean section				0.698[f]
Yes	6(17.1)	6(27.3)	12(21.0)	
No	28(80.0)	16(72.7)	44(77.2)	
Unknown	1(2.9)	0(0.00)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Attended antenatal care clinic				0.056[f]
Yes	18(51.4)	15(68.2)	33(57.9)	
No	13(37.1)	2(9.1)	15(26.3)	
Unknown	3(8.57)	4(18.2)	7(12.3)	
Missing data	1(2.9)	1(4.5)	2(3.5)	
Total	35(100.0)	22(100.0)	57(100.0)	
Gestational age at booking				0.301[c]
Less than 20 weeks	9(25.7)	8(36.4)	17(29.8)	
Above 20 weeks	10(28.6)	8(36.4)	18(31.6)	
Unbooked	13(37.1)	4(18.2)	17(29.8)	
Unspecified	3(8.6)	2(9.1)	5(8.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Anaemia during pregnancy				0.476[c]
Yes	22(62.9)	11(50.0)	33(57.9)	
No	9(25.7)	7(31.8)	16(28.1)	
Missing data	4(11.4)	4(18.2)	8(14.0)	
Total	35(100.0)	22(100.0)	57(100.0)	
Rapid Plasma Reagin				0.098[f]
Non-reactive	21(60)	16(72.7)	37(65.0)	
Unknown	11(31.4)	2(9.1)	13(22.7)	
Missing data	3(8.6)	4(18.2)	7(12.3)	
Total	35(100.0)	22(100.0)	57(100.0)	

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196 Table 2 (continued)

Variable	Values n (%), median [!QR]			p-value
	Before COVID-19 (March 2018 - February 2019)	During COVID-19 (March 2020 - February 2021)		
Booking weight (kg), range and median				0.580"
Minimum	43	36	36	
Maximum	563	117	563	
Median (!QR)	60155 - 75]	76[47.75- 93.5]	54.5(53 85.25)	
Booking weight (kg)				0.378'
<90	14(40)	10(45.5)	24(42.1)	
2:90	2(5.7)	4(182)	6(10.6)	
Missing data	19(54.3)	8(36.4)	27(47.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Mid Upper Arm Circumference (cm), range, and median				0.790"
Minimum	21	20	20	
Maximum	245	39	245	
Median [!QR]	25123 - 29.75]	245[21 - 35]	25(22.38-30.75]	
Mid Upper Ann Circumference (cm), range, and median				
$12	3(8.6)	5(22.7)	8(14.0)	0.101'
23-33	11(31.4)	5(22.7)	16(28.1)	
2:34	1(2.9)	4(182)	5(8.8)	
Missing data	20(63.6)	8(36.4)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Height (cm)				0.505
Minimum	151	143	8	
Maximum	164	185	16	
Median [!QR]	155[152-162]	159.5(151-163]	5	
Height (cm)				
:Sl50	3(8.6)	2(9.1)	5(8.8)	1.000'
2:151	12(34.3)	12(54.5)	24(42.1)	
Missing data	20(57.1)	8(36.4)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
COVID-19				<0.00 I'
Yes	0(0.0)	9(40.9)	9(15.8)	
No	35(100.0)	13(59.1)	48(84.2)	
Total	35(100.0)	22(100.0)	57(100.0)	
Antenatal complications				0.906'
Present	15(42.9)	10(45.5)	25(43.9)	
Absent	14(40.0)	10(45.5)	24(42.1)	
Missing data	6(17.1)	2(9.1)	8(14.0)	
Total	35(100.0)	22(100.0)	57(100.0)	

Table 2 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID-19 (March 2018 – February 2019)	During COVID-19 (March 2020 – February 2021)	Total	
Antenatal complication types				0.107[f]
Unbooked	13(37.1)	4(18.2)	17(29.8)	
Preterm labour	1(2.9)	0(0.00)	1(1.8)	
Genital warts	1(2.9)	0(0.00)	1(1.8)	
Hypertension in pregnancy	5(14.3)	3(13.6)	8(14.0)	
Lower respiratory infection	3(8.6)	0(0.00)	3(5.3)	
*COVID-19	0(0.00)	4(18.2)	4(7.0)	
**Others	4(11.4)	4(18.2)	8(14.0)	
Missing data	8(22.8)	7(31.8)	15(26.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Management of antenatal complications met expectation				0.545[f]
Yes	7(20.0)	4(18.2)	11(19.3)	
No	2(5.7)	4(18.2)	6(10.6)	
Sometimes	6(17.1)	4(18.2)	10(17.5)	
Missing data	20(57.1)	10(45.5)	30(52.6)	
Total	35(100.0)	22(100.0)	57(100.0)	

*Of the 9 women diagnosed with COVID-19, a total of 4 were diagnosed during the anteratal period.

**Others were women who had more than one complication. Anemia was defined as a hemoglobin concentration less than 11g/dl in the first trimester. Abbreviations: c, Chi-square test; f, Fisher exact test; m, Mann-Whitney U test.

More than half of the women (66.7%, 38/57) had a pre-existing chronic medical condition before pregnancy with the most common being HIV infection (61.4%, 35/57). Of the women with HIV infection, the median CD4 count (cells/μl) was 312 (IQR 39–459), comprising 116 (11.5–378) before and 331 (197–667) during COVID-19-P, p = 0.133. Of the 35 women with HIV infection 19 (54.3%) were on antiretroviral therapy: 12/35 before and 7/22 during COVID-19-P. The second most common chronic condition was chronic hypertension which occurred in 5.3.% (3/57) of all the women (two before and one during COVID-19-P).

The most frequent antenatal complication that developed after booking was hypertensive disorders of pregnancy (HDP) and this occurred in 14.3% (5/35) and 13.6% (3/22) of the women before and during COVID-19-P, respectively. The second most common antenatal complication was COVID-19, which occurred in 7.0% (4/57) of all the women but, understandably, there was none before the COVID-19 period. Overall, 9 (15.8%) women had COVID-19 in total (Table 2). Except for COVID-19, there was no statistical difference between the two study periods in terms of the antenatal profile, COVID-19 status, and chronic medical condition (Table 2).

3.3 Trends in maternal deaths, births, and maternal mortality ratio

The trends in MDs and live births during the four-year study period are summarized in Table 3. Of the 58 MDs, 60.34% (35/58) occurred before and 39.66% (23/58) during COVID-19-P. The live births increased from 5 166 in the first year of the study, reaching a peak of 5 947 in the third year (March 2020 to February 2021) and thereafter declining to 5 476 in the fourth year. There was also a steady decline in MDs from 17 to 11 during the four-year period. Similarly, the iMMR decreased steadily from 329.07 to 200.88 deaths per 100 000 live births (Fig 2).

Table 3. Twelve-monthly trends in maternal deaths, live births, and maternal mortality ratio

Variables	Before COVID-19		During COVID-19	
	Mar 2018 – Feb 2019	Mar 2019 – Feb 2020	Mar 2020 – Feb 2021	Mar 2021 – Feb 2022
Maternal deaths	17	18	12	11
Live births	5166	5866	5947	5476
Total births	5333	6070	6153	5647
Maternal mortality ratio per 100 000 live births	329.1	306.9	201.8	200.9

Overall, the maternal mortality ratio per 100 000 live births was 317.3 before COVID-19, 201.3 during COVID-19 and 258.3 during the 4-year period of the study.

Fig 2. Twelve-monthly trends in maternal mortality ratio

Abbreviations: Feb, February; Mar, March.

Table 4 shows the six-monthly MDs, deliveries, and iMMR across 8-point periods. The jointpoint regression analysis of the six-monthly iMMR showed a statistically significant declining trend of 9.59% between February 2018 - August 2018 and September 2021 – February 2022 (Fig 3). The six-monthly trends in iMMR are shown in Fig 4.

Table 4. Six-monthly maternal deaths, deliveries, births, and maternal mortality ratio

Period	Maternal deaths	Total deliveries	Total births	Total live births	Maternal mortality ratio per 100 000 live births
Before COVID period					
Feb 2018 – Aug 2018	10	2685	2720	2632	379.9
Sep 2018 – Feb 2019	7	2571	2613	2534	276.2
Mar 2019 – Aug 2019	11	2942	2979	2884	381.4
Sep 2019 – Feb 2020	7	2956	3091	2982	234.7
During COVID-19 period					
Mar 2020 – Aug 2020	6	3126	3188	3090	194.2
Sep 2020 – Feb 2021	6	2920	2965	2857	210.0
Mar 2021 – Aug 2021	6	2865	2906	2816	213.1
Sep 2021 – Feb 2022	5	2689	2741	2760	181.2

Fig 3. Jointpoint regression analysis of the six-monthly maternal mortality ratio

Explanation: The Annual percentage change (APC) denotes six monthly percentage change. There were 8 time periods of six months each: 1 – 8 (square dots), consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

Fig 4. Six-monthly trends in maternal mortality ratio

Explanation: Abbreviation: MMR, Maternal mortality ratio. There were 8 time periods 1 - 8, consisting of 1 = Feb 2018 – Aug 2018; 2 = Sep 2018 – Feb 2019; 3 = Mar 2019 – Aug 2019; 4 = Sep 2019 – Feb 2020; 5 = Mar 2020 – Aug 2020; 6 = Sep 2020 – Feb 2021; 7 = Mar 2021 – Aug 2021; and 8 = Sep 2021 – Feb 2022.

3.4 Intra- and post-partum outcomes and their complications

There was no statistically significant difference between the two periods in terms of intra- and post-partum outcomes and their complications (Table 5). Nonetheless, 40.4% (23/57) of the women delivered vaginally (16/35 before and 7/22 during COVID-19-P) compared to 33.3% (19/57) who delivered via caesarean delivery (9/35 before and 10/22 during COVID-19-P). A respective total of 21% (12/57) and 5.3% (3/57) were undelivered and had a laparotomy for ectopic pregnancy. The most common indication for caesarean delivery was fetal distress which occurred in 12.2% (7/57) of the women with 4/35 before and 3/22 during COVID-19-P.

Table 5. Intra- and post-partum outcomes and their complications

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Mode of delivery n (%)				0.266[f]
Vaginal birth	16(45.7)	7(31.8)	23(40.4)	
Caesarean delivery	9(25.7)	10(45.5)	19(33.3)	
Undelivered	7(20.0)	5(22.7)	12(21.0)	
Laparotomy for ectopic pregnancy	3(8.6)	0(0.00)	3(5.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Indication for caesarean section, n (%)				0.367[f]
Fetal distress	4(11.4)	3(13.6)	7(12.2)	
Previous uterine surgery	0(0.0)	3(13.6)	3(5.3)	
Preeclampsia with severe Features	3(8.6)	1(4.5)	4(7.0)	
Maternal resuscitation	2(5.7)	1(4.5)	3(5.3)	
Breech presentation	0(0.00)	1(4.5)	1(1.8)	
Severe COVID-19 Pneumonia	0(0.00)	1(4.5)	1(1.8)	
Had vaginal delivery	16(45.7)	7(31.8)	23(40.4)	
Missing data	10(28.6)	5(22.7)	15(26.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Blood loss (ml) during childbirth, range and median				0.845[m]
Minimum	50	200	50	
Maximum	2000	1100	2000	
Median [IQR]	500[200 – 950]	500[250– 1000]	500[275– 1000]	
Blood loss (ml) during childbirth, n (%)				0.413[f]
≤499	6(17.1)	3(13.6)	9 (15.8)	
500 – 999	4(11.4)	3(13.6)	7(12.3)	
1000 – 1499.9	1(2.9)	3(13.6)	4(7.0)	
≥1500	2(5.7)	0(0.00)	2(3.5)	
Missing data	22(62.9)	13(59.1)	35(61.4)	
Total	35(100.0)	22(100.0)	22(100.0)	
Apgar score				0.116[m]
Minimum	0	0	0	
Maximum	10	10	10	
Median (IQR)	7.5[0 – 9]	9 [6.25 – 10]	8[0-10]	

Table 5 (continued)

Variable	Values n (%), median [IQR]			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Apgar score category, n (%)				
Stillbirth (0)	0(0.0)	0(0.0)	0(0.0)	Constant
Asphyxia (1 - 6)	0(0.0)	0(0.0)	0(0.0)	
Normal Apgar (≥7)	15((42.9)	14(63.6)	29 (50.8)	
Undelivered	7(20)	5(22.7)	12(21.0)	
Ectopic laparotomy	3(8.6)	0(0.0)	3(5.3)	
Missing data	10(28.5)	3(13.6)	13(22.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Birth weight (g)				0.226[m]
Minimum	450	890	450	
Maximum	3400	3400	3400	
Median, IQR	1850[1187.5 – 2625]	2400[1395 – 3000]	2130[1300 – 2750]	
Birth weight (gram) category, n (%)				0.563[f]
≤999g	4(11.4)	1(4.5)	5 (8.8)	
1000-2499 g	8(22.9)	6(27.3)	14 (24.6)	
≥2500 g	6(17.1)	6(27.3)	12 (21.0)	
Missing data	17(48.6)	9(40.9)	26(45.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Gender of baby, n (%)				0.755[c]
Male	10(28.6)	7(31.8)	17(29.8)	
Female	8(22.9)	7(31.8)	15(26.3)	
Undelivered	7(20.0)	5(22.7)	12(21.0)	
Ectopic pregnancy	3(5.3)	0(0.0)	3(5.3)	
Missing data	7(20.0)	3(5.3)	10(28.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Intrapartum complications, n(%)				0.013[f]
Yes	0	4(18.2)	4(7.0)	
No	26(74.3)	11(50.0)	37(64.9)	
Missing data	9(25.7)	7(31.8)	16(28.1)	
Type of intrapartum complications, n (%)				Constant
Eclampsia	0(0.00)	1(4.5)	1(1.8)	
Abruption placenta	0(0.00)	1(4.5)	1(1.8)	
Fetal Distress	0(0.00	1(4.5)	1(1.8)	
Cephalo-pelvic disproportion	0(0.00)	1(4.5)	1(1.8)	
33 complication	26(74.3)	11(50.0)	37(64.9)	
Missing data	9(24.7)	7(32.0)	16(28.0)	
Total	35(100.0)	22(100.0)	57(100.0)	

Table 5 (continued)

Variable	Values n (%) median [IQR]			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Postpartum complications, n (%)				0.859[c]
Yes	17(48.6)	12(54.6)	29(50.9)	
No	8(22.9)	5(22.7)	13(22.8)	
Missing data	10(28.6)	5(22.7)	15(26.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of postpartum complication, n (%)				0.349[f]
Postpartum hemorrhage	4(11.4)	2(9.1)	6(10.5)	
Puerperal Sepsis	5(14.3)	1(4.5)	6(10.5)	
Venous thromboembolism	1(2.9)	2(9.1)	3(5.3)	
Cardiac arrest during caesarean delivery	2(5.7)	1(4.5)	3(5.3)	
Preeclampsia with severe features	4(11.4)	3(13.6)	7(12.3)	
Perforated Uterus	1(2.9)	0(0.00)	1(1.8)	
COVID-19	0(0.00)	3(13.6)	3(5.3)	
No complication	18(51.5)	10(45.6)	28(49.1)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: c, Chi-square test; f, Fisher exact test; m, Mann-Whitney U test.

The median APGAR score for the two periods was 8 (0–10) comprising 7.5 (0–9) before and 9 (6.25–10) during COVID-19-P, p = 0.116. The median birth weight (g) for the babies of the women in the two periods was 2 130 (1 300–2 750) comprising 1 850 (1 187.5–2 625) before and 2 400 (1 395–3 000) during COVID-19-P, p = 0.226. The most common postpartum complications before COVID-19-P were puerperal sepsis 14.3% (5/35), postpartum hemorrhage (PPH) 11.4 (4/35), and preeclampsia with severe features 11.4% (4/35). During the COVID-19-P, the most common postpartum complications were COVID-19 13.6% (3/22), preeclampsia with severe features 13.6% (3/22), and postpartum haemorrhage (PPH) 9.1% (2/22).

3.5 Critical care admissions and mechanical ventilation

Table 6 shows critical care admissions and mechanical ventilation. More percentage of women, 38.1% (8/22), were admitted to the high care unit during COVID-19-P compared to 31.4% (11/35) before the pandemic. Before COVID-19-P, sepsis was the most common indication for high-care admission, occurring in 14.3% (5/35) of the women. However, during COVID-19-P, the most common indications for high-care admission were preeclampsia with severe features 9.1% (2/22) and cardiac diseases 9.1% (2/22).

Table 6. Critical care admissions and mechanical ventilation

Variable	Values n (%)			*p-value*
	Before COVID-19	During COVID-19	Total	
Admission to high care unit, n (%)				0.700[c]
Yes	11(31.4)	8(38.10)	19(33.3)	
No	24(68.6)	14(63.6)	38(66.7)	
Total	35(100.0)	22(100.0)	57(100.0)	
Indications for admission to high care unit, n (%)				0.418[f]
Preeclampsia with severe features	2(5.7)	2(9.1)	4(7.0)	
Postpartum haemorrhage	1(2.9)	1(4.5)	2(3.5)	
Sepsis	5(14.3)	1(4.5)	6(10.5)	
Cardiac diseases including supraventricular tachycardia	3(8.6)	2(9.1)	5(8.8)	
Other indications	0(00)	2(9.1)	2(3.5)	
Straight admission to ICU	24(68.6)	14(63.6)	38(66.7)	
Total	35(100.0)	22(100.0)	57(100.0)	
Admission to intensive care unit (ICU), n (%)				1.000[c]
Yes	25(71.4)	15(68.2)	40(70.2)	
No	10(28.6)	6(27.2)	16(28.0)	
Missing data	0 (0)	1(4.5)	1(1.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Indication for admission to ICU, n (%)				0.151[f]
Acute respiratory distress	12(34.3)	8(36.4)	20(35.1)	
GCS of 7 and less	3(8.6)	3(13.6)	6(10.5)	
Inotropic support	9(25.7)	2(9.1)	11(19.3)	
Cardioversion	2(5.7)	0(0.00)	2(3.5)	
Fluid resuscitation	0(0.00)	2(9.1)	2(3.5)	
Not admitted to ICU	9(25.7)	7(31.8)	16(28.1)	
Total	35(100.0)	22(100.0)	57(100.0)	
Mechanical ventilation, n(%)				0.026[c]
Yes	26(74.3)	11(52.38)	37(64.9)	
No	7(20.0)	11(47.62)	18(31.6)	
Missing data	2(5.7)	0(00)	2(3.5)	
Total	35(100.0)	22(100.0)	57(100.0)	

Resuscitation describes women who were admitted to ICU to control central venous pressure. Abbreviations: GCS, Glasgow Coma Scale.
c: Chi-square test; f: Fisher exact test.

The proportion of women admitted to the intensive care unit (ICU) was 71.4% (25/35) before and 68.2% (15/22) during COVID-19-P. The most common indications for ICU admission were acute respiratory distress at 34.3% (12/35) before and 36.4% (8/22) during COVID-19-

P, p = 0.151. The rate of mechanical ventilation was 74.3% (26/35) before and 52.38% (11/22) during COVID-19-P (p = 0.026).

3.6 Time of hospital admission and hour of maternal death

Table 7 shows the time of hospital admission and hour of MDs, with no statistically significant difference between the periods before and during COVID-19-P, p>0.05. Most hospital admissions occurred during the day. However, the majority of MDs occurred during the night: 74.3% (26/36) before and 59.1% (13/22) during COVID-19-P, p = 0.494. Most of the MDs occurred outside the Obstetrics and Gynaecology department, 81.8% before and 87.7% during COVID-19-P.

Table 7. Time of hospital admission and maternal death

Variable	Values n (%)			*p*-value
	Before COVID-19	During COVID-19	Total	
Time of hospital admission, n (%)				0.192[f]
Day (08:00 - 15:59 hours)	20(57.1)	7(31.8)	27(47.4)	
Evening (16:00 - 18:59 hours)	6(17.1)	5(22.7)	11(19.3)	
Night (19:00 - 07:59 hours)	9(25.7)	10(45.5)	19 (33.3)	
Total	35(100.0)	22(100.0)	57(100.0)	
Time of death, n (%)				0.494[f]
Day (08:00 - 15:59 hours)	5(14.3)	5(22.7)	10(17.5)	
Evening (16:00 - 18:59 hours)	4(11.4)	4(18.2)	8(14.1)	
Night (19:00 - 07:59 hours)	26(74.3)	13(59.1)	39(68.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Department where death occurred, n (%)				0.411[f]
Within Obstetrics and Gynaecology Department	3(8.6)	4(18.2)	7(12.3)	
Outside Obstetrics and Gynaecology Department but including ICU setting	32(91.4)	18(81.8)	50(87.7)	
Total	35(100.0)	22(100.0)	57(100.0)	

Abbreviations: c, Chi-square test; f, Fisher exact test; ICU, intensive care unit

3.7 Primary and final causes of maternal deaths

Table 8 shows the primary and final causes of MDs. Preeclampsia with severe features (22.9%) was the most common primary cause of MDs before COVID-19-P, with tuberculosis being second (20%), early pregnancy bleeding third (17.2%), and sepsis fourth (14.3%). Conversely, COVID-19 (31.8%), and tuberculosis (13.6%) were the first and second most common primary causes of MDs during the COVID-19-P, with the third most common cause being four conditions namely PPH, pulmonary embolism, sepsis and preeclampsia with severe features, each having a percentage occurrence of 9.1%. The primary causes of MD for the two periods ($p = 0.009$), however, were statistically significantly different.

Table 8. Causes of maternal deaths

Variable	Values n (%)			*p*-value
	Before COVID (January 2018 – December 2019)	During Covid (January 2020 – December 2021)	Total	
Primary causes of death				0.009[f]
Postpartum haemorrhage	2(5.7)	2(9.1)	4(7.0)	
Pulmonary embolism	2(5.7)	2(9.1)	4(7.0)	
Tuberculosis	7(20)	3(13.6)	10(17.5)	
Sepsis	5(14.3)	2(9.1)	7(12.3)	
Early pregnancy bleeding	6(17.2)	0(0.00)	6(10.5)	
Preeclampsia with severe features	8(22.9)	2(9.1)	10(17.5)	
COVID-19	0(0.00)	7(31.8)	7(12.3))	
*Others	5(14.3)	4(18.2)	9(15.8)	
Total	35(100.0)	22(100.0)	57(100.0)	
Final causes of death				0.092[f]
Cardio-pulmonary arrest	11(31.4)	11(50.0)	22(38.6)	
Respiratory failure	7(20)	6(27.3)	13(22.8)	
Renal failure	1(2.9)	1(4.5)	2(3.5)	
Liver Failure	0(0.00)	1(4.5)	1(1.8)	
Multiple organ Failure	16(45.7)	3(13.6)	19(33.3)	
Total	35(100.0)	22(100.0)	57(100.0)	

*Others comprised Kaposi sarcoma, advanced cervical cancer, suicide, ingestion of unsafe herbal medication, parasuicide, and supraventricular tachycardia. Early pregnancy bleeding includes those from ectopic pregnancy, miscarriages, and termination of pregnancy.
Abbreviations: c, Chi-square test; f, Fisher exact test.

The most common final causes of MDs before and during COVID-19-P were multiple organ failure (45.7%) and cardiopulmonary arrest (50%); however, there was no statistically significant difference in the final causes of MDs between the two periods (p = 0.092).

3.8 Avoidable factors

The patient-, healthcare professional- and administrative-related AVFs associated with the MDs are presented in Table 9. Each woman had at least one AVF that was associated with her management. Before COVID-19-P, patient, healthcare professional, and administrative-related AVFs occurred in 62.9% (22/35), 62.9% (22/35), and 57.1% (20/35) of the women,

respectively. Before COVID-19-P, the most common patient-, healthcare professional- and patient-related AVFs were not having any antenatal care, wrong treatment, and lack of ICU/high care spaces respectively.

338 Table 9. Patient, healthcare worker, and administrative-related avoidable factors

Avoidable facLOr (A VF)	Values n (%)			p-value
	Before COVID-19	During COVID-19	Towl	
Pre."i.ence of any AVF,n (%)				
Present	35(100.0)	22(100.0)	57(100.0)	
Absent	0(0.0)	0(0.0)	0(0.0)	
Total	35(100)	22(100)	57(100.0)	
Patient-related AVF, n (%)				1.000
Present	22(62.9)	8(36.4)	30(52.6)	
Absent	13(37.1)	14(63.6)	27(47.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Types of patient-related avoidable factors. n				
Had no aruenaia.l care	13		16	
Defauhed antenarnl clinic	0	1	1	
Refused medic.al treaunenl	0	0	0	
Commenced antenatal clinic after 20 weeks' gestation	6			
Declined medical treatment			4	
Delayed seeking medical treatment	11	4	15	
Unsupervised delivery at home			2	
Total	33	12	45	
Healthcare profe."i-sional related AVF, n (%)				0.272
Present	22(62.9)	12(54.5)	34(59.6)	
Absent	13(37.1)	10(45.5)	23(40.4)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type.of healthcare professional-related AVF.n				
Lack of critical care skills			11	
Delay in referral	7	2	9	
Wrong diagnosis despite classical fearures of a disease	6	1	7	
Wrong tremmem	10	2	12	
Delay in seeking senior outpuLS	4	3	7	
Total	34	12	46	
Administrative-related AVF, n (%)				0.779
Present	20(57.1)	11(50.0)	31(54.4)	
Absenl	15(42.9)	11(50.0)	26(45.6)	
Total	35(100.0)	22(100.0)	57(100.0)	
Type of adminis.trJli ve-related AVF, n				
Delay in referral (trans.pon.alion)		1		
Communication breakdown		3		
Lack of equipment		0		
Lack of trained medical staff	4	0	4	
Lack of ICU and high care dependent uniLspace	II	7	18	
Lack of medicine	0		1	
Tolal	29	12	41	

Multiple avoidable factors were associated with the management of mme patients,and thi. made the calculation of percentage. of the type of avoidable factor less infonnati\•e. Additionally, . ome avoidable factor. may be grouped into more than one category: hllwever, the current grouping in this table was based011. 1lCcific circumstance. associated with each case after a robust panel discussion. AbbreviatioM: c, Chi-square test.

During COYID-19-P, patient-, healthcare professional- and administrative-related AVFs occurred in 36.4% (8/22), 54.5% (12/22), and 50% (I1/22) of the women, respectively. In the same period, the most common patient-, healthcare professional- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability ofICU/high care beds, in this order.

Table 10 shows the AVFs associated with the management of causes of the MDs. The conditions associated with the greatest number of AVFs were pregnancy-related infection and **HOP.** The most common AVF associated with non-pregnancy-related infections was poor compliance to antiretroviral drugs: with frequencies of 12 before and eight during COVID-19-P. The most frequent AVF associated with the management of **HOP** was delay in referral to a tertiary hospital: JO before and four during COVID-19-P.

359 Table 10. Avoidable factors associated with management of causes of maternal death

Avoidable factors	Values, n		
	Before COVID-19	During COVID-19	Total
Avoidable factors related to non-pregnancy-related infection, n	14	10	24
Defaulted TB treatment multiple times	8		II
CD4- not checked by a healthcare worker	6		II
Poor compliance to ARV treatment	12		20
Avoidable factors related to hype11ensive disorders of pregnancy, n	13	6	19
Delay in referral to tertiary hospital	JO	4	14
Pre-eclampsia screening test not performed healthcare worker	9	2	II
Avoidable factors related to obstetric haemorrhages, n	5		
Problem recognition of bleeding ectopic pregnancy	3	0	
INR not requested in fUFD	1	0	
Poor surgical skills at caesarean delivery	1	I	
Delay in taking a relook decision	0	2	
Avoidable factors related to puerper.al sepsis	4	I	
Problem recognition of puerperal sepsis	1	0	
Delay in deciding to perform T AH		0	
Problem recognition of RPOC		0	
Avoidable factors related to ectopic pregnancy.	2		
Obvious features of ectopic pregnancy misdiagnosed and the patient received misoprostol for termination of pregnancy on request until shock	0		
Classical features of ectopic pregnancy missed at the medical ED where lhe patient was brought for symptomatic anemia and urine beta hCG test was not performed		0	
Classical features of ectopic pregnancy missed treated as pelvic inflammatory disease in pregnancy		0	
Avoidable factors related to medical and surgical conditions	9	4	12
Suicide	0		
Late presentation of advanced cervical cancer in pregnancy	2		
Failure to refer cardi.:tc patients to a higher level of care	2	2	4
Inadequate critical care	4	0	4
Delay in diagnosis of obvious pelvie source of sepsis in lhe medical ward	1	O	1

360 Multiple a\·oidable facto were associated with the management of some patients. Additionally,some a\·oidable foctors may be grouped into
361 more than one categoiy: howe,•er, the current gmuping in thi. table was ba.<:ed on .i;;pedfic circumstances a. sociated with each case after a
362 robust panel discussion. Abbreviations: ARV, Anti-retn:wiral drugs: ED, Emergency Dcpanmen1; INR, International nonnalizetl ratio: IUFD,
363 Intrauterine fetal death: RPOC,Rc1ai1KXlprexluct of conception: TAH, Total abdominal hysterectomy; TB, Tuben-:ulosi. .

4. Discussion

4.1 Main findings

Most of the women before and during COVID-19-P were aged 25-34 years, single, lived in the Kenneth Kaunda district, were unemployed, and neither smoked nor used any illicit substance. The number of MDs and iMMRs was more before than during COVID-19-P. Both the MDs and iMMR decreased yearly during the study period, with a 9.59% declining trend in the six-monthly iMMR between the first and last six months of the study period. The first, second, and third most common causes of MDs before COVID-19-P were preeclampsia with severe features, tuberculosis, and early pregnancy bleeding, in this order. During COVID-19-P, the first and second most common causes of MD were COVID-19 and tuberculosis, respectively, with the former attributable to 31.8% (7/22) deaths. The third most common causes of MD during COVID-19-P were **PPH,** pulmonary embolism, sepsis, and preeclampsia with severe features. The percentage of the women who had mechanical ventilation was statistically significantly more before than during the COVID-19-P. Most MDs occurred at night, with most hospital admissions occurring during the day.

Avoidable factors were associated with all the MDs. Before COVID-19-P, the most frequent patient-, healthcare professional-, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care bed spaces, respectively. During COVID-19-P, the most common patient-, healthcare worker- and administrative-related AVFs were delay in seeking medical treatment, lack of critical care skills, and unavailability ofTCU/high care bed spaces, respectively.

387 *42 lnrerprerarion*

388 Most of the women who died were between the ages of25 and 34. The predominant age group
389 in this study was similar to the findings of Thomas et al. where participants were between the
390 ages of 14 and 45 [17). Contrarily, Rulisa et al. found that the most common age group was 16
391 - 57 years (18]. In non-pregnant adults, however, death due to COVID-19 affected mainly
392 individuals aged 60 years and above (19].
393
394 In South Africa, some patients access healthcare across health districts due to reasons such as
395 referral patterns, logistical concerns, and financial cost considerations (20]. In this study
396 setting, the restriction of movements during the COVID-19 period did not affect the total
397 deliveries and births because they were no decline in their rates (Tables 3 and 4). However,
398 Bailey et al 2023 reported an increase in birth rates among native Americans during the
399 COVID-19-P [21]. In contrast, Wachuli et al. found that COVID-19 severely impacted
400 maternity services in their setting and was associated with a reduction in the number of
401 antenatal care revisits [22]. However, the index study setting was a referral centre that
402 prioritized maternity services. Since most of the deceased were from the same district (Kenneth
403 Kaunda) as the study setting, restrictions in movement/transportation might not have impacted
404 the referral pattern before and during COVID-19-P.
405
406 Surprisingly, there was a decline in MDs and iMMR during COVID-19-P as compared to the
407 period before COVlD-19. Ln South Africa, the overall iMMR per 100 000 live births was 98.8
408 in 2019 (before COVID-19-P), 126.1 in 2020, 148.1 in 2021, 109.9 in 2022, and 102.1 in 2023
409 [23]. Compared to the pre-pandemic levels, COVID-19 caused an increase in iMMR in 2020
410 and 2021 but there was a decline observed in 2022 [23). Similarly, Bei\ova et al reported an
411 increase in iMMR during the COVID-19-P [24]. Most plausibly, the decline in MD and iMMR

412 at the index study setting, despite the occurrence of COVlD-19-P, might be because of
413 continuous and sustained improvement in maternity care at the facility. The number of full-
414 time specialist obstetricians and gynaecologists doubled from two to four in 2019 and was
415 retained. Moreover, additional clinical staff were allocated to essential services such as
416 maternity care during the COVID-19-P. onetheless, the differences in the clinical profile of
417 patients, coupled with the virulence of the SARS-COV-2 strain and other supportive care,
418 might also have played a role in the differences in trends observed at various settings by
419 different researchers. For instance, the rate of mechanical ventilation was lower during than
420 before COVID-19-P. Given that COVID-19 is a highly infectious respiratory disease, the lower
421 rate of mechanical ventilation during the pandemic, may indicate that the deceased pregnant
422 women who presented with COVID-19 in the study setting did not have severe respiratory
423 complications requiring mechanical ventilation.
424
425 otably, the first, second, and third most common causes of MDs before COVID-19-P were
426 preeclampsia with severe features, tuberculosis, and early pregnancy bleeding, respectively.
427 This is similar to the findings of another study showing that among the most common causes
428 ofMDs before COVID-19-P were sepsis, haemorrhage such as those from abortion, and HDP
429 particularly preeclampsia [18). During COVID-19-P, the first most common cause of MD was
430 COVID-19, with tuberculosis being the second. Similar to our findings, the most common
43 I causes of MDs during COVlD-19-P have been reported by other investigators as COVID-19
432 pneumonia and associated acute respiratory distress [25).
433
434 All the MDs were associated with an AVF, which could possibly have prevented some of the
435 deaths. This information re-echoes the findings of the National Committee on Confidential
436 Enquiry into Maternal Deaths in South Africa which showed that 58% of the MDs in South

Africa had been preventable [23]. During the COVID-19-P, the most common patient, healthcare professional, and administrative-related AVFs in our study were delay in seeking medical treatment, lack of critical care skills, and lack of ICU/high care dependent unit bed spaces, respectively. Before the COVID-19 period, though, the most frequent patient, healthcare professional, and administrative-related AVFs were failure to book for antenatal care, administration of wrong treatment, and lack of ICU/high care dependent unit bed spaces, respectively. Notably, some of the AVFs were related to a specific clinical condition (Table 10), and this becomes a clarion call for development and adherence to clinical protocols. This need has been highlighted by Sadler et al. who showed that the management of obstetric conditions such as puerperal sepsis and PPH was associated with substandard care and lack of problem recognition [26].

4.3 Strengths and limitations

There were some missing data because of the retrospective design of the study. To address this limitation, missing data were reported and excluded from the calculation of p-values. The results of the histopathological autopsies were not available to the investigators, because in South Africa forensic autopsies are usually conducted for MDs and the reports are only made available to the family members of the deceased. Moreover, there was a restriction in performing histopathological autopsy during the early period of COVID-19-P due to concerns about disease spread. Furthermore, data on any MD that may have occurred outside the hospital setting such as at home were not available, and we are therefore unable to provide further comments about them. Additionally, the non-inclusion in the study of pregnant women who survived (including those with near misses) did not allow for comparison of the outcomes (diagnosis and interventions) in the deceased and survivors. However, our study design is acceptable, as MD analysis in many countries often does not include survivors [10, 23].

A major strength of our study is its comparative design, and the relatively long duration (four years) studied. This study is therefore among a few with these attributes, particularly among those conducted in low- and middle-income countries. Furthermore, the medical records of the MDs were discussed by the investigators during scheduled meetings to ensure the appropriateness of the data collected. This approach prevents bias during data collection.

4.4 Recommendations and generalizability

The following are measures that may be implemented at the study setting and similar healthcare facilities to improve care. Firstly, staff training is required to prevent healthcare professional-related AVFs. Among the required training are critical care skills as well as diagnosis and treatment of common causes of MDs. Clinical staff should be rostered to undergo practical simulated training in common obstetric conditions. An example is the Essential Steps in Managing Obstetric Emergencies training.

Secondly, there is a need to streamline administrative factors by improving the healthcare system. Notable among them is the need to provide additional bed spaces for women needing critical care. Thirdly, there is a need to retain staff to avoid losing the gains made (declining iMMR). This may be in the form of seamless human resource services to staff and improving other conditions of services that will facilitate staff growth. Fourthly, there is a need to investigate the preponderance of MDs that occur at night to develop measures to address factors associated with them. It is possible that the nocturnal MDs may be partly related to poor staffing at night because there are already afternoon and weekend specialist handover ward rounds at the study setting. Fifthly, it is crucial to educate pregnant women about the need for antenatal care. In South Africa, over 68.3% of pregnant women attend antenatal care before 20 weeks of

pregnancy [27]; however, there is a need to aim at a 100% uptake. The use of community-based healthcare workers and preventing barriers to access to prenatal care will improve antenatal clinic attendance (5, 28].

5. Conclusion

The **iMMR** was lower during than before the COVID-19 period, with a steady yearly decline. Improved resource availability (particularly employment of specialist clinical staff before COYID-19-P) and the preferential resource allocation to maternity services during the pandemic may be responsible for the decline in the **iMMR.** Therefore, a major determinant of the outcome of a clinical condition is the implementation of appropriate interventions.

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Conflict of interest

None

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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I ONGOMBE LUNDA Student number: 2620318 I am a student registered for the degree of MMED

(Obstetricss and Gynaecology) in the academic year 2025

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

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