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# Investigating the causes of maternal mortality in Razavi Khorasan based on forensic medical records during the years 2015 to 2022

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## Abstract

**Background** Maternal mortality is among the main indicators of health in nations. Identifying the causes of maternal mortality is crucial in designing preventive interventions. Therefore, this study aimed to evaluate the causes of maternal mortality during 8 years.

**Methods** This descriptive-analytical study was conducted on the archived cases of maternal mortality in the Forensic Medicine Department of the Khorasan Razavi Province between March 2013 and March 2022, but as no data was available for the first two years, maternal mortality data for 8 years was evaluated. Demographic characteristics, midwifery data, pregnancy care method, pregnancy care and delivery agent, insurance type, and confirmed cause of death were compared between the first and last five-year periods of the study.

**Results** Overall, 250 cases of maternal mortality were identified in the study period. The prevalence of indirect and unrelated causes of maternal mortality was significantly higher in the last four-year period compared to the first four-year period ($p < 0.001$). The most common direct causes of maternal mortality in both periods were postpartum hemorrhage, eclampsia and gestational hypertension complications; and postpartum infection. Coronavirus disease 2019 (COVID-19) was the most common cause of maternal mortality in the last four-year period but the other common indirect causes of maternal mortality (cardiovascular disease and pulmonary embolism) were similar between the two periods. The most common unrelated cause of maternal mortality was accidents.

**Conclusions** Postpartum maternal mortality was higher than intrapartum period. Bleeding was still the main cause of maternal mortality. Despite the progress in prenatal care, it is necessary to improve intrapartum and postpartum quality of care.

**Keywords** Maternal mortality, Pregnancy, Retrospective study, Healthcare

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**Text box 1. Contributions to the literature**

- Maternal mortality rate is high in Razavi Khorasan Province, Iran.
- Bleeding, hypertension and infection were the common recent causes of maternal death.
- Indirect and unrelated causes of maternal death was more common in the past four years.
- The risk of death was high among less educated mothers and the age range of 18–35 years.

## Introduction

Maternal mortality due to complications of pregnancy and childbirth is among the important indicators of development in countries and is influenced by various social and economic factors [1, 2]. Iran has achieved significant success (82.5%) in reducing maternal mortality through implementing maternal health programs and optimal healthcare coverage [2]. Although the maternal mortality rate in pregnancy is decreasing in our country, it is noteworthy to know that the causes of maternal mortality have remained the same, among which, bleeding, infection, embolism and eclampsia are still the most important causes [2–6].

Furthermore, 5.2% of maternal deaths were due to direct causes, and 4.3% were due to indirect causes, which are still not well defined in studies. In Iran, the lowest maternal mortality rate was recorded in Tehran, the capital of Iran, (15.8), while the highest maternal mortality rate was recorded in the Sistan and Baluchistan province (384 per 100,000 live births). In a systematic review study conducted in Iran, it was determined that the maternal mortality rate in Razavi Khorasan was 29.3% during the 2008–2018 period and that the province had the second highest maternal mortality rate in Iran after Sistan and Baluchistan province [7].

The decreasing trend in maternal mortality rate in Iran (74.6% reduction) was the highest among the 10 Middle-East nations [8].

Since injuries, pregnancy related complications, and deaths are preventable in many cases, examining changes in the causes of maternal mortality in the current decade can help find risk factors or preventive factors and suggest practical solutions to improve the health status of pregnant mother [9, 10]. As the Razavi Khorasan province has the second highest record of maternal mortality rate in Iran, it is important to identify the causes of maternal mortality in this province to help improve maternal health and reduce the shortcomings in maternal care.

This study aimed to determine the eight-year prevalence of maternal mortality in pregnancy and examine the changes in its causes in the last four years compared to the first four years in Khorasan Razavi province. These findings can identify the hidden factors that might affect maternal mortality and help healthcare decision makers provide solutions to prevent the persistent causes of maternal mortality in the province.

## Methods

The current descriptive-analytical retrospective cross-sectional study was conducted based on convenient sampling. The study population consisted of all the cases of maternal mortality referred to the Forensic Medicine Department of the Khorasan Razavi Province between March 2015 and March 2022. Data collection was performed using a researcher-made checklist, which was developed based on the research objectives using the latest scientific sources [7, 11]. The content validity of the questionnaire was approved based on expert opinion. The expert team included two forensic medicine specialists, two doctorates in reproductive health, and two gynecologists.

The checklist included demographic, midwifery, pregnancy care method, pregnancy care agent, delivery agent, type of insurance, and the confirmed cause of death sections. Data were extracted from the Forensic Medical Department archives. In case of incomplete records, the accompanying persons of the deceased mother were contacted and the information was completed through phone interviews. If no one could be contacted, only valid information about the deceased mother was used in the determination of maternal mortality rate and further analyses.

The inclusion criteria for this study were death during pregnancy, childbirth, or postpartum (42 days after delivery), maternal mortality registered from 2015 to 2022, maternal mortality being registered in the Forensic Medicine Department of the Khorasan Razavi Province, mortality due to direct, indirect, or unrelated causes. Records with incomplete data on demographic characteristics or fertility were only included in determining the maternal mortality rate and were excluded from analytical statistics, including the relationship between maternal mortality and pregnancy characteristics.

In the samples whose file information included incomplete demographic or fertility characteristics, they were considered only in the examination of the frequency of maternal death and its causes, and were excluded in the examination of the relationship between death and fertility characteristics.

Information on maternal mortality was not available for the 2012–2014 period. Therefore, a total of 250 maternal death records with direct, indirect, or unrelated causes were obtained between 2015 and 2022.

### Ethical considerations

This study was approved by the National Committee of Ethics in Biomedical Research (Code: IR.LMO.

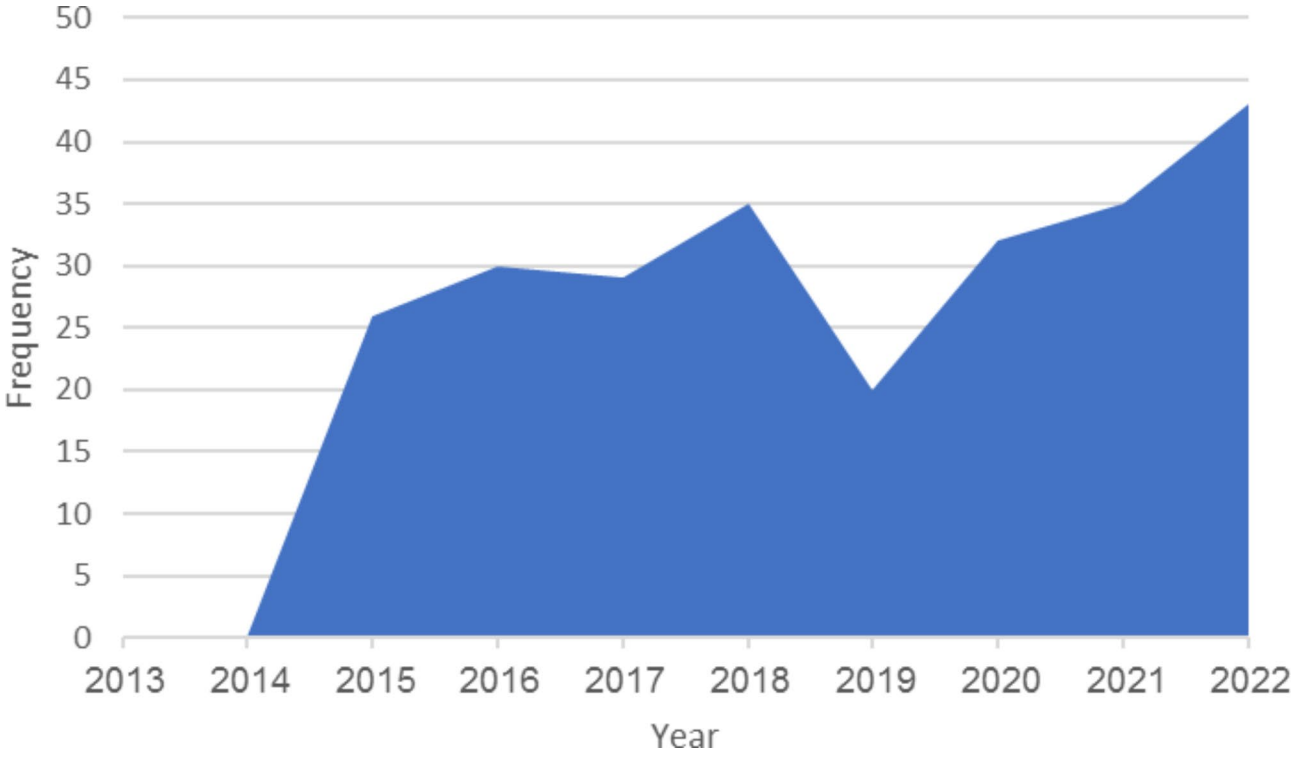


**Fig. 1** The trend in the frequency of maternal mortality referred to the Forensic Medicine Department of the Khorasan Razavi between 2014 and 2022

REC.1400.027). The subjects' anonymity was preserved in the final report and manuscript preparation based on the ethical codes. The findings were reported to the Forensic Medicine Department of the Khorasan Razavi Province.

### Statistical analysis

Data analysis was done using the statistical Package for Social Sciences (SPSS) software version 22. Descriptive analysis was performed using frequency and percentage. A comparison of the distribution pattern of study variables between periods was performed using the chi-square test. The level of statistical significance was considered as $p<0.05$.

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## Results

Due to the importance of the causes of death, the types of maternal mortality and its common causes were discussed first. Then the demographic characteristics of the deceased were stated and finally, the characteristics of pregnancy and pregnancy care were evaluated.

**Table 1** Comparison of the distribution pattern of the causes of maternal mortality between 2015–2018 and 2019–2022 periods

| Causes of maternal mortality | 2015–2018 | | 2019–2022 | | *p* |
|---|---|---|---|---|---|
| | Frequency | % | Frequency | % | |
| Direct causes | 44 | 44 | 56 | 56 | < 0.001* |
| Indirect causes | 25 | 22.12 | 88 | 77.8 | |
| Unrelated causes | 11 | 29.7% | 26 | 70.2% | |

* Significant difference based on the chi-square test

### Common causes of maternal mortality

In the current study, 250 records of maternal mortality were identified between 2015 and 2022. The lowest rate of maternal mortality ($n=20$) was reported in 2019 and the highest rate ($n=43$) was reported in 2022 (Fig. 1).

A comparison of the distribution pattern of the causes of maternal mortality between the first and last four years of the eight-year study period was presented in Table 1. There was a significant difference in the distribution pattern of the causes of maternal mortality between the two time periods ($p<0.001$) indicating a higher rate of indirect and unrelated causes of death in the last four-year period.

The most common direct cause of maternal mortality in the first and last four-year periods of the current study was postpartum hemorrhage followed by eclampsia and gestational hypertension complications in the second place, and postpartum infection in the third place. Comparison of the frequency distribution of direct causes of

**Table 2** Comparison of the frequency distribution of direct causes of maternal death between 2015–2018 and 2019–2022 periods

| Causes of maternal mortality | 2015–2018 | | 2019–2022 | | *p* |
|---|---|---|---|---|---|
| | Frequency | % | Frequency | % | |
| Postpartum hemorrhage | 21 | 48.8 | 24 | 51.2 | 0.635 |
| Eclampsia and gestational hypertension complications | 14 | 35.8 | 25 | 62.4 | |
| Postpartum infection | 6 | 50 | 6 | 50 | |
| Septic abortion | 3 | 50 | 3 | 50 | |

The chi-square test was used for the comparison

**Table 3** Comparison of the frequency distribution of indirect causes of maternal mortality between 2015–2018 and 2019–2022 periods

| Causes of maternal mortality | 2015–2018 | | 2019–2022 | | *P* |
|---|---|---|---|---|---|
| | Frequency | % | Frequency | % | |
| COVID-19 | 0 | 0.0 | 34 | 100.0 | 0.081 |
| CVD | 11 | 45.0 | 17 | 60.7 | |
| Pulmonary embolism | 7 | 42.0 | 11 | 58.0 | |
| Cerebrovascular accidents | 2 | 42.9 | 3 | 57.1 | |
| TTP | 1 | 27.3 | 2 | 72.1 | |
| Epileptic seizure | 1 | 27.3 | 2 | 72.1 | |
| Asthma attack | 0 | 0.0 | 2 | 100.0 | |
| Pneumonia | 1 | 50.0 | 1 | 50.0 | |
| Dystocia | 0 | 0.0 | 1 | 100.0 | |
| Gestational fatty liver | 0 | 0.0 | 1 | 100.0 | |
| Leukemia | 0 | 0.0 | 1 | 100.0 | |
| DKA | 0 | 0.0 | 1 | 100.0 | |
| Gastrointestinal (Mesenteric ischemia) | 0 | 0.0 | 1 | 100.0 | |

COVID-19: Coronavirus Disease 2019, CVD: Cardiovascular Disease, TTP: Thrombotic Thrombocytopenic Purpura, DKA: Diabetic Keto Acidosis

The chi-square test was used for the comparison

maternal death in the first and last four-year periods was not significantly different. That is, the order of the direct causes of death was the same in both periods under study, postpartum hemorrhage was the first cause, gestational hypertension and its complications were the second cause, and postpartum infection was the third cause of maternal mortality (Table 2).

The most common causes of bleeding leading to maternal mortality were uterine atony (6%), followed by uterine rupture (4%). The most common gestational hypertension complications leading to maternal mortality were Hemolysis, Elevated Liver enzymes and Low Platelets (HELLP) syndrome (6.4%), eclampsia (3.6%), and intracranial hemorrhage (ICH) (2%). The most common cause of death due to postpartum infection was disseminated intra-abdominal infection (4%) and chorioamnionitis (1.2%).

The most common indirect causes of maternal mortality in the first four-year period were cardiovascular diseases (CVD) (42.3%), pulmonary embolism (26.9%), and cerebrovascular accidents, including brain tumor, brain aneurysm, and stroke, (7.6%). However, in the last four-year period of the study coronavirus disease (COVID-19) (43%), CVD (18.9%), and pulmonary embolism (13.9%) were the most common causes of maternal mortality respectively (Table 3).

The most common unrelated cause of maternal mortality was motor vehicle accidents (6.8%), other accidents including debris, and animal bites (3.2%), poisoning (0.2%), suicide (1.6%), and murder (1.2%) (Table 4).

#### Demographic characteristics of the deceased mothers

The average age of the deceased mothers was 31.5±6.68 years old. Majority (67.2%) of the deceased mothers were in the 18–35 years age group. The maternal mortality rate in this age group was doubled in the last four-year period compared to the first four-year period. The highest mortality rate was reported in deprived urban areas (69.7%) and among mothers with the educational level of less than high school diploma (63%). The lowest maternal mortality rate was reported among mothers with Bachelor's degree and above (10%). The majority (92.8%) of the deceased mothers were housewives and maternal mortality rate among working mothers was very low (7%). The majority of the deceased mothers were Iranian (90%). In 80% of the deceased mothers, the spouses were from the working class. The cause of death in 14.8% of the mothers was unrelated to pregnancy. All these mothers lived in deprived urban areas and on the outskirts of the city. 11% of the deceased mothers were drug abusers.

**Table 4** Comparison of the frequency distribution of unrelated causes of maternal mortality between 2015–2018 and 2019–2022 periods

| Causes of maternal mortality | 2015–2018 | | 2019–2022 | | *p* |
|---|---|---|---|---|---|
| | Frequency | % | Frequency | % | |
| Motor vehicle accidents | 6 | 35.3 | 11 | 64.7 | 0.272 |
| Other accidents (debris, animal bite) | 1 | 20.0 | 5 | 82.0 | |
| Suicide | 0 | 0.0 | 4 | 100.0 | |
| Burn | 2 | 100.0 | 0 | 0.0 | |
| Murder | 1 | 33.3 | 2 | 66.7 | |
| Poisoning | 1 | 20.0 | 4 | 80.0 | |

The chi square test was used for the comparison

### Pregnancy characteristics and care

The mean gravida of the deceased mothers was 2.95±1. The maternal mortality rate was higher in the second pregnancy. 5% of the deceased mothers had more than one child. The mean gestational age was 29.98±10.49 weeks. The most common place of death was hospital (81.3%), followed by home (9.6%), road emergency sites (3.2%), the site of accident (1.2%), and ambulance (0.4%). The most common type of delivery in deceased mothers was cesarean Sect. (44.2%) (Table 5).

A comparison of maternal mortality rates between the first and last four-year periods of the study is presented in Fig. 2. There was no significant difference in terms of the time of death between the study periods ($p$=0.668).

Comparison of the main causes of maternal mortality between two time periods (2015–2018 and 2019–2022) is presented in Table 6. There was a significant difference in the distribution patter of causes of maternal mortality between the time periods ($p$=0.019) indicating that bleeding and postpartum hypertension and eclampsia were more common in the later period compared to the former.

## Discussion

The current study was conducted with the aim of determining the eight-year (2015–2022) maternal mortality and examining the changes in the causes of maternal mortality in the Khorasan Razavi Province between the first and last four-year periods of the study. It was determined that out of 250 cases of maternal mortality records, between 2015 and 2022, of 100 cases were due to direct causes, 113 cases were due to indirect causes, and 37 cases were due to causes that were unrelated to pregnancy. The most common causes of maternal mortality in the first four-year period of the study was direct causes, while indirect causes were the most common causes of maternal mortality in the last four-year period of the study.

The current study indicated that the most common direct causes of maternal mortality were hemorrhage, eclampsia and gestational hypertension; postpartum infection, and infectious abortion. The frequency of postpartum hemorrhage and eclampsia and complications of gestational hypertension increased significantly in the last four-year period compared to the first four-year period of the study. The World Health Organization also announced in 2019 that obstetric hemorrhage, pregnancy-related infection, gestational hypertension disorders, and unsafe abortion were still the main causes of maternal mortality worldwide [12].

The results of the study by Boutin et al. in Canada, which was conducted between 2013 and 2017, showed that 13% of the causes of maternal mortality were direct causes, among which, the most common was postpartum infection followed by gestational hypertension and its complications; postpartum hemorrhages, and spontaneous or induced abortion complications [13]. However, Yadav et al. (2022) reported that the most common direct causes of maternal mortality in India were hemorrhage and gestational hypertension and its complications [14]. Other studies conducted in India indicated that the most common direct cause of maternal mortality was hemorrhage [15–17]. These findings were in line with the findings of the current study due to the similarities between the countries as developing countries.

The results of the studies conducted in Iran have shown no change in the direct causes of maternal mortality in the last three decades and only the order of these causes was different between different areas of the country. This phenomenon is partly due to the quality of care and the quality of hospital services and partly due to demographic and social changes, including changes in the age of pregnancy, education level, and health literacy. Although the direct causes of maternal mortality have not changed, maternal mortality due to the main three direct causes has decreased, which can be due to the improvement in the quantity of care and equipment, permanent access to educated midwives and gynecologists; and an increase in women's awareness [18, 19]. The current study showed that uterine atony, uterine rupture, and placental abruption were the most common causes of hemorrhage leading to death.

The second cause of maternal mortality in the current study was eclampsia and gestational hypertension

**Table 5** Frequency of maternal death according to individual factors and fertility history during 2015–2022

| Variable | | Frequency (%) |
|---|---|---|
| Maternal age | < 18 years | 6 (2.4) |
| | 18–35 years | 166 (67.2) |
| | > 35 years | 75 (30.4%) |
| Education level | Some high school | 144 (58.2%) |
| | High school graduate | 50 (19.9%) |
| | Bachelor's degree | 26 (10.4%) |
| | Illiterate | 21 (4.8%) |
| | Master's degree | 2 (0.8%) |
| | Unknown | 5 (2%) |
| Maternal occupation | Housewife | 233 (92.8%) |
| | Employee | 7 (2.8%) |
| | Free lance | 4 (1.6%) |
| | Unknown | 4 (1.6%) |
| | Student | 2 (0.8%) |
| Gravida | 1 | 43 (20.0%) |
| | 2–4 | 133 (61.9%) |
| | > 5 | 39 (18.1%) |
| Nationality | Iranian | 226 (90.0%) |
| | Non-Iranian | 21 (4.8%) |
| Place of residence | Urban | 175 (69.7%) |
| | Rural | 50 (19.9%) |
| | City outskirts | 23 (9.2%) |
| Spousal occupation | Free lance | 203 (80.9%) |
| | Employee | 28 (11.2%) |
| | No spouse (Single mother) | 6 (2.4%) |
| | Unknown | 12 (4.8%) |
| Drug abuse | | 27 (10.8%) |
| Prenatal care agent | Obstetrics and gynecologist | 120 (47.8%) |
| | Unknown | 56 (22.2%) |
| | Comprehensive healthcare center and obstetrics and gynecologist | 54 (21.1%) |
| | Urban comprehensive health care center | 49 (19.5%) |
| | Midwife in governmental section | 42 (16.7%) |
| | No prenatal care | 31 (12.4%) |
| | Unknown | 53 (21.1%) |
| Type of delivery | Cesarean section | 111 (44.2%) |
| | No delivery | 60 (23.9%) |
| | Normal vaginal delivery | 53 (21.9%) |
| | Abortion | 14 (5.6%) |
| | Curettage | 5 (2.0%) |

complications. In a study by Lisonkava et al. on delivery data from Washington State from 2000 to 2008, a 33% increase was reported in the rate of early-onset preeclampsia before 34 weeks gestation, which was associated with 10-fold increase in the risk of maternal mortality compared to women without this condition [20] Theilen et al. studied the long-term mortality risk and life expectancy following recurrent gestational hypertension and reported that pre-eclampsia was significantly associated with severe maternal complications, especially cardiovascular, respiratory, and renal complications. Gestational hypertension has long-term health consequences, including a 2-fold increase in the risk of all-cause mortality before age 50, and increased mortality related to diabetes, ischemic heart disease, and stroke. These long-term consequences occurred more among women who had experienced gestational hypertension and its complications at least twice [21].

In the current study, all maternal mortality cases due to gestational hypertension were due to eclampsia and complications of gestational hypertension. HELLP syndrome (6.4%), seizures (3.6%), and cerebral hemorrhage (2%) were the gestational hypertension complications that led to maternal mortality. Therefore, identifying women at risk of cardiovascular diseases during reproductive age

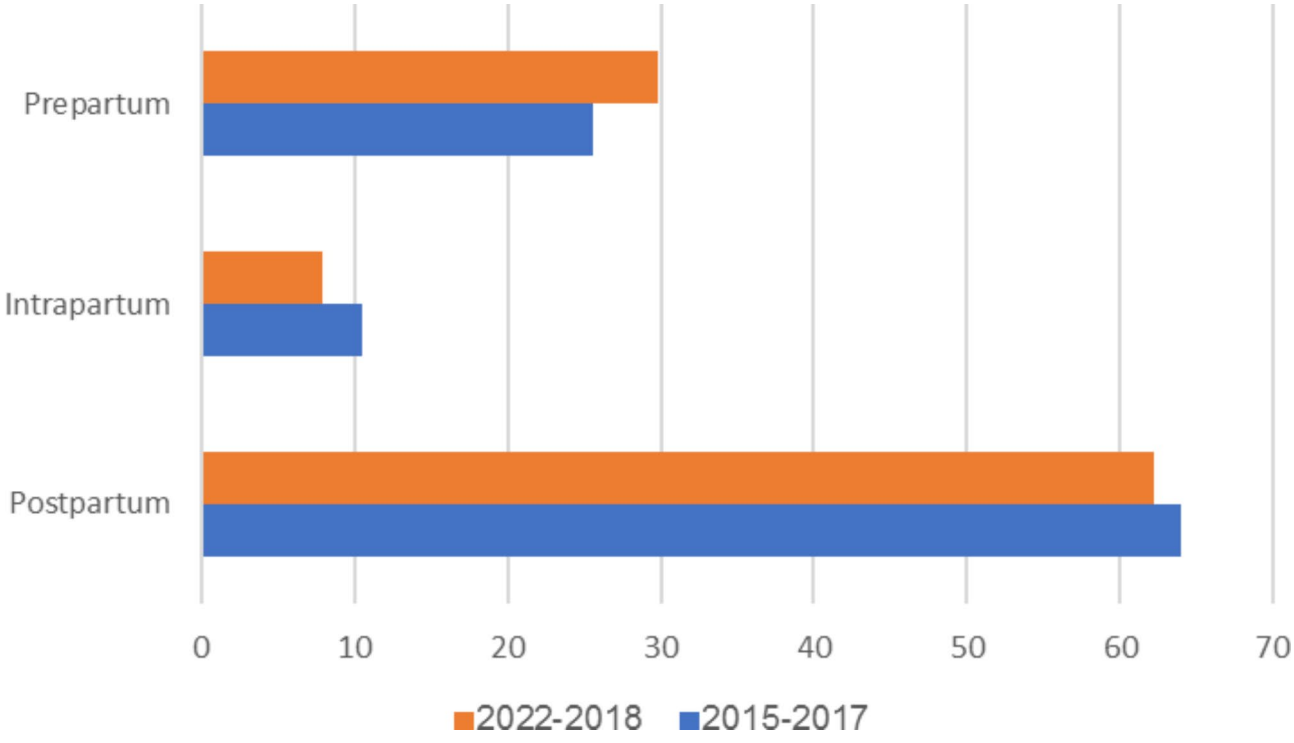


**Fig. 2** Percentage of maternal mortality as per time of death between 2015-2018and 2019–2022 periods

**Table 6** Comparison of the distribution patterns of the causes of maternal mortality between 2015–2018 and 2019–2022 periods

| Cause of maternal mortality | 2015–2018 | 2019–2022 | *p* |
|---|---|---|---|
| Bleeding | 41 (27.3%) | 109 (72.7%) | 0.019* |
| Illegal abortion | 1 (50%) | 1 (50%) | |
| Criminal abortion | 2 (100%) | 0 (0%) | |
| Postpartum infection | 6 (50%) | 6 (50%) | |
| Postpartum hypertension and eclampsia | 14 (37.8%) | 23 (62.2%) | |
| Postpartum hypertension and eclampsia and infection | 0 (0%) | 2 (100%) | |

The chi square test was used for the comparison

* Significant difference

is an opportunity to intervene and optimize long term health [21].

The third factor that led to maternal mortality was postpartum infection, among which, pelvic peritonitis and chorioamnionitis were the two main causes of postpartum infection. A retrospective study in England also stated that pelvic peritonitis was the most common cause of maternal mortality [22].

The results of the current study showed that the rate of infection was 58.3% in cesarean delivery which was significantly higher compared to normal vaginal delivery (41.7%). Cesarean section is an important risk factor for postpartum infections (wound infection, endometritis, or urinary tract infections) [23].

The fourth leading cause of maternal mortality in the current study was infectious abortion complications and accounted for 1.2% of the cases of maternal mortality. All these cases were due to unsafe abortion. Based on a previous report, about 20 million unsafe abortions are conducted in the world each year. The World Health Organization defines unsafe abortion as terminating an unwanted pregnancy by unskilled people, or in an environment that lacks minimum medical standards, or both conditions. Unsafe abortions increase in societies that have restrictive abortion laws. This will be a worrying issue in the increase of maternal mortality [24].

In the current study, the most common indirect causes of maternal mortality in the first four-year period of the study were cardiovascular diseases, pulmonary embolism, and cerebrovascular accidents, including brain tumor, cerebral aneurysm, and stroke, but in the last four-year period of the study, COVID-19, cardiovascular diseases, and pulmonary embolism were the most common indirect causes of maternal mortality. In the current study, a 10% increase was observed in the number of the cases of pregnancy with a history of cardiovascular

disease, and a 16% increase was observed in the incidence of pulmonary embolism. In a cross-sectional study from 2003 to 2019, Collier et al. identified cardiovascular diseases, including cardiomyopathy, myocardial infarction, and cerebrovascular accidents as the cause of more than 33% of pregnancy-related deaths [25]. They also observed a 25% increase in the number of the cases of pregnancy with a history of heart disease, which was hypothesized to be due to the increase in the age of pregnancy, increase in multiple pregnancies, or advancements in diagnostic methods [25]. Similarly, the current study showed a 10% increase in the number of the cases of pregnancy with a history of cardiovascular disease. Therefore, strategies to reduce modifiable risk factors for cardiovascular diseases, including obesity, hypertension, and diabetes, in women of reproductive age may help to reduce the incidence of cardiovascular diseases and their major side effects. In addition, multidisciplinary care should be provided to pregnant women who have cardiovascular disease (collaboration between midwives, gynecologists and cardiologists) to assess the risk for known and unknown heart diseases and prevent maternal mortality [25].

Due to the outbreak of the COVID-19 pandemic in Iran since February 2020, the most common indirect cause of maternal mortality was COVID-19 [26]. Due to the importance of this disease, it was dealt with in another study.In the current study, accidents, injuries, poisoning due to drug abuse, suicide, and murder comprised majority of the unrelated causes of maternal mortality. In the current study, suicide and drug poisoning were observed among mothers with more than 3 pregnancies. Kontanis et al. (2018) observed that the share of deaths caused by suicide and substance abuse increased disproportionately in the state of Michigan, which was partly related to the increased prevalence of perinatal mood and anxiety disorders and serious mental illnesses, which could be the reason for death up to one year after delivery [27].

It seems that maternal suicides during the perinatal period are different from non-perinatal suicides in several ways. First, more violent methods are used in perinatal suicides (hanging or jumping from great height) compared to those of non-perinatal suicides [28–30]. Second, during pregnancy and the first year postpartum, majority of women have significantly more contact with health care professionals compared to any other time in their lives, yet suicide remains a leading cause of maternal mortality. Therefore, regular access to health care services alone may not be sufficient to encourage mothers to seek help for suicidal thoughts and/or behavior and ultimately to prevent suicide-related maternal mortality [31].

In terms of individual factors, the highest maternal mortality rate was found among the 18–35 years age group, followed by above 35 years group. Carvalho et al. showed that the highest maternal mortality rate among Brazilian mothers occurred between the age of 20 and 39 years old [32]. In the current study, the lowest maternal mortality rate was in the less than 18 years old group, which could be due to the low prevalence of marriage.

The mean gravida of the deceased mothers was $2.95 \pm 1$. About 18% of them had more than 4 pregnancies. Yadav et al. also reported that most maternal deaths occurred in mothers with more than 4 pregnancies in India in 2022 [14].

Education and literacy are other important social factors that determine maternal mortality [33, 34]. In the current study, more than half of the deceased mothers had less than a high school degree or were illiterate, and the lowest mortality rate was observed among mothers with Bachelor's degree and above. This finding confirms the principle of better self-care in mothers with higher education. Furthermore, majority of the deceased mothers were housewives, and the maternal mortality rate in working mothers was very low. In the study by Carvalho et al., (2020) in Brazil, 84.2% of deceased mothers had less than middle school and high school education, and 64.2% were housewives [32].

Studies show an inverse correlation between the level of education of women and maternal mortality. Alvarez et al. (2009) showed that maternal mortality rate was lower in women with high education in Africa [35]. In other words, women who are literate and have a higher level of education can access the necessary information to make decisions about their health care, and therefore are less likely to die during or after pregnancy compared to those with lover education level [36, 37].

Demographically, most of the deceased mothers were Iranian. The large number of health centers in city outskirts and the continuous follow-up of health care workers has decreased maternal mortality in these areas, but maternal mortality rate in the village was higher than the city outskirts. The current study showed that the most common causes of maternal mortality was living in the rural area were distance from the city and delay in referral to medical centers. In the current study, majority of the deceased mothers lived in deprived areas of the city. The high percentage of crime and addiction in these areas could affect the physical and mental health of mothers. Based on the report by the World Health Organization in 2019, high maternal mortality rate in some regions of the world could indicate inequality in access to quality health services and highlights the gap between the rich and the poor [12]. In the current study, the effects of these three social factors can be evidenced among mothers with substance abuse. Records of these mothers indicated no or incomplete pregnancy care, living in deprived areas, low level (below high school degree), and not having insurance. Howell et al. considered social inequality as an important factor in maternal mortality. They emphasized

on the role of social inequality in the occurrence of severe complications and maternal mortality. Social, ethnic and racial inequality are among social conditions that can increase the risk of adverse pregnancy outcomes and maternal mortality [38–41].

In the current study, most of the deaths occurred in hospital, followed by home, emergency ward, the site of accident, and in ambulance. Majority of studies conducted in other countries reported that most cases of maternal mortality occurred in hospital [42, 43]. Furthermore, the highest maternal mortality rate was related to mothers who gave birth in the hospital, and death at home was the second most common due to the lack of facilities. Various reasons exist for this finding among which, the most important reasons include labor medicalization and pregnancy care in Iran. The therapeutic and technocratic approach to childbirth in Iran has resulted in the attitude among women to refer to hospitals. Furthermore, the easy access to hospitals could be considered as another reason for the observed priority for in-hospital delivery [44–46].

Furthermore, refusal to conduct autopsy by the family members resulted in the ambiguity of the exact cause of death in pregnant women. The inequality in facilities and the ratio of treatment staff to mothers in private and public hospitals, the difference in socioeconomic status and the inequality in the provision of services have caused most low-income and high-risk mothers refer to crowded hospitals and low-risk mothers to private hospitals [46, 47].

In terms of the pregnancy care agent, most of the deceased mothers were seen by gynecologists and less than half of the cases received simultaneous care from gynecologists and comprehensive health care centers. It seems that the collaboration of gynecologists and midwives in comprehensive health care centers and private clinics will lead to better control and timely diagnosis of complications, and reduce maternal mortality. About one third of the deceased mothers did not receive any care at all. In the study by Carvalho et al. (2020) in Brazil, 20.5% of deceased women did not receive any prenatal care [32].

The current study showed that the most cases of maternal deaths occurred after childbirth and the least deaths occurred during childbirth, which was in line with the findings of previous studies in other countries [14, 25, 48–52]. According to the data analysis in the current study, the mean interval between childbirth and maternal death was 11 days. Therefore, it can be hypothesized that postpartum women neglect the importance of the postpartum period visits. A systematic and meta-analysis study conducted in Iran in 2023 showed that the most common causes of death in Iranian women during the last decade were caesarean section and post-surgical accidents, lack of effective and quality care during the postpartum period, and the inexperienced delivery agents, and low health literacy among pregnant women. Postpartum bleeding and infections are considered as the most important causes of maternal mortality in the postpartum period [53]. As the rate of Caesarean section is as high as 47.9% in Iran, the increase in postpartum mortality could be anticipated [48].

The findings of the current study indicated that the median interval between birth and maternal death was 11 days, which were similar to the findings of the study conducted by Shobha et al. (2019) in India who reported that 41% of women died within one week after delivery [50].

In the present study, 10.8% of the deceased mothers were drug abuser. The mean age of these mothers was 31.59±6.68 years, which was 4 years less than the overall mean age in the current study. The mean gestational age at pregnancy termination was 29.98±10.49 weeks. In the current study, postpartum hemorrhage was the leading cause of death among the mothers with substance abuse, and gestational hypertension and postpartum infection were equally the second common cause of maternal mortality in mothers with substance abuse, while in mothers without substance abuse, postpartum infection was the third. This difference indicated that infection was more common among mothers with substance abuse, which might be due to unsanitary living conditions. This finding was not observed in previous studies [49, 54, 55].

### Strengths

One of the strengths of this study was an extensive and comprehensive evaluation of maternal mortality during the last decade.

### Limitations

- In this study, the basis of the information collected through interviews and hospital and forensic medical reports included in the file is considered as the final cause of death.
- Failure to include information related to the type and quality of prenatal care in the maternal death file.

## Conclusion

The most important causes of maternal mortality in the first and last four-year periods of the study were direct and indirect causes, respectively. The most common direct causes of maternal mortality were postpartum hemorrhage, eclampsia, gestational hypertension, and postpartum infection. Uterine atony, uterine rupture, and placental abruption were the main three causes of bleeding leading to death. HELLP syndrome, convulsions, and cerebral hemorrhage were the gestational

hypertension-related complications leading to death. Furthermore, pelvic peritonitis and chorioamnionitis were the main two causes of postpartum infection. Furthermore, the current study indicated that the maternal mortality was more prevalent in postpartum period compared to intrapartum.

The most common causes of postpartum death were postpartum hemorrhage followed by postpartum infection, and gestational hypertension. The most common indirect causes of maternal death were CVD, Pulmonary embolism, and cerebrovascular accidents (tumor, aneurysm, and stroke) in the first four-year period, while COVID-19, CVD, and pulmonary embolism were the most common causes of indirect maternal mortality in the last four-year period of the study.

Based on the findings of the current study, the factors leading to maternal mortality can be divided as follows: first, environmental, social and economic factors and conditions of society, including living on municipal outskirts, low socioeconomic status, low education and health literacy level. Second, factors related to the quality and delivery methods of health and medical services. Third, factors related to lifestyle and health behaviors of the society, including drug addiction, alcohol, and insufficient hygiene. These findings indicate the important role of the government in eliminating discrimination, poverty, and heath inequalities. Furthermore, the use of methods to increase the quality of prenatal and postnatal care in the municipal outskirts and underprivileged areas should be considered by stakeholders. Creating a suitable platform for promoting normal vaginal delivery and creating holistic approaches instead of technocratic approach in childbirth and practical and scientific strengthening of midwives can help reduce maternal mortality. Furthermore, the level of health literacy should be increased in the society. Women should be empowered to refer to reliable sources for their health problems.

Therefore, the authors suggest the following dimensions to improve maternal mortality; (a) activities that require direct government intervention, and (b) activities that require the direct intervention of the people. These dimensions include correct and complete provision of health and treatment services with optimal quality by the government to all sections of the society to improve the health of the society. In other words, the improvement of the economic, social, political and cultural factors in the country can be the basis for providing and promoting be considered health outcomes. Applying appropriate and effective penalties for health and medical personnel who neglect maternal care. Applying appropriate and efficient incentives for committed personnel in the field of health and treatment. Empowering management and decision-making in all members of the society and increasing health literacy level so that individuals can identify and control the factors affecting their health. Therefore, active participation of people in health care is important besides the actions made by the government. In the meantime, lifestyle factors, including culture, traditions, beliefs, attitudes, values, and the perception of health concepts, directly or indirectly affect the health of the entire society. Improving health at the same time as providing health services that require providing security, housing, education, food, and employment, proper environment and social equality guarantee the appropriate health services for all members of the society. These rights are respected in the Constitution of the Islamic Republic of Iran. Realizing and promoting the right to health requires sufficient commitment of the people and the government. The government should be committed to the people to invest more for health.

Suggestions for future research:

1. Improving the health literacy of families through midwives, investigating the effect of mothers' self-care on reducing pregnancy and childbirth complications.
2. Investigating the effect of promotion of physiological childbirth, and work independence among midwives on intrapartum and postpartum complications and consequences.
3. Investigating the impact of one-year empowerment programs in women with low economic and social status on the incidence of physical and mental diseases during pregnancy.
4. A comparative study of the effect of comprehensive quality management versus inspection-based management in delivery rooms, efficient incentive and punishment systems for maternal care personnel in reducing medical malpractice to reduce maternal mortality.

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**Author contributions**
Study concept and design: M. S., and A. N.; analysis and interpretation of data: S. D., and M. S.; drafting of the manuscript: S. D. and M. S; critical revision of the manuscript for important intellectual content: M. S., T. FN., and S. D.; statistical analysis: S. D.

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**Data availability**
The datasets generated and analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by Committee of Ethics in Biomedical Research (Code: IR.LMO.REC.1400.027). Anonymity of the subjects was preserved in the final report and manuscript preparation based on the ethical codes. As the data collection was performed from the recorded data of the Forensic Medicine Department, informed consent was obtained from next of kin of the deceased individuals.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

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