

Root-Cause Analysis of Maternal Mortality in Fars Province, Southern Iran 2014: Negligence Is the Prime Suspect

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Received February 2020; Revised and accepted September 2020

Abstract

Objective: we aimed to carry out an applied methodological tool, using Root-Cause Analysis (RCA), to determine the main causes of maternal mortality in Fars province, south of Iran, in 2014.

Materials and methods: This is a case-series study and was conducted based on a careful examination of records and verbal autopsy with the family of the deceased person and their medical care team. Using RCA, quantitative dynamic modeling was done to display the overall impacts of different causes on maternal mortality. Finally, sensitivity analysis was done to determine the magnitude of contribution of each root-cause of maternal mortality.

Results: Totally, all 10 maternal deaths with Maternal Mortality Rate (MMR) of 13.4 per 100,000 births, were recorded in the maternal surveillance system during 2014. The RCA results revealed that the root-causes of maternal mortality were ignorance and negligence (50%), delay in diagnosis (30%), delay in service provision in the first 24 hours after delivery (10%), and undesirable health care (10%). The results of sensitivity analysis in different scenarios revealed that medical negligence had the highest contribution to maternal mortality.

Conclusion: Although maternal surveillance system stated some causes such as hemorrhage to be responsible for maternal deaths, the RCA showed that root-causes such as medical neglects had a fundamental role. Therefore, maternal mortality can be prevented by reforming the health care system and training all service providers, especially for high-risk mothers.

Keywords: Maternal Mortality; Root-Cause Analysis; Sensitivity Analysis; Quantitative Dynamic Modeling

Introduction

Maternal death is not just an indicator for health,

instead it's a strategic indicator for sustain and comprehensive development, and highly correlated with literacy rate, personal and family income and other economical, and cultural factors (1). In the Islamic Republic of Iran, the maternal mortality rate (MMR) has decreased from 83 deaths per 100,000 live

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births in 1990 to 23 per 100,000 in 2013 (a 72% reduction in MMR). In developing countries direct causes (specially hemorrhage) are the leading cause of maternal deaths, but in developed countries leading causes are mainly indirect factors (2). More than 50% of all maternal deaths have been occurred in only six countries in 2008 include: India, Nigeria, Pakistan, Afghanistan, Ethiopia, and the Democratic Republic of the Congo (3). Although more pregnant women are accessing the health services, lack of adequate trained and motivated personnel at these sites probably resulted in the unfortunate women being picked up and referred late to a tertiary center (4). The estimated number of maternal mortality worldwide in 2008 and 2013 were reported about 358000 and 293,000 by WHO. Different countries have different portions of this global rate from 5-10/100000 in developed countries to 85-1570/100000 in Oceania and Sub-Saharan African countries (5). Aimed to prevention of pregnancy complications following implementing a national educational program in Iran, pregnancy complications were reduced significantly. bleeding or spotting, urinary tract complications, blurred vision and severe headache, premature labor pain, anemia, severe vomiting, inappropriate weight gain, endometritis, urinary incontinence, breast abscess or mastitis, wound infection, and bleeding was significantly reduced, compared to before intervention (6). Investigate the health literacy of pregnant women in the south of Iran indicated that 15.5% of the subjects had an inadequate level of health literacy; 41.7% had a border-line level of health literacy, and 42.8% had an adequate level of literacy. Significant correlations were found between each of these variables and the subjects' level of health literacy: education, age, occupation and care provision during pregnancy ($p < 0.05$) (7). Despite different studies and advances, in the 21st century the causes of maternal mortality have not significantly changed compared with the past century and again maternal hypertension, hemorrhage and infections are the leading causes of maternal mortality (8). Studying the causes of maternal mortality is always of particular importance because some of the common causes of maternal mortality such as septic abortion, uterine rupture, eclampsia and postpartum hemorrhage can be prevented in many cases (9). The main causes of maternal mortality in adolescents were from direct causes: hypertensive disorders, hemorrhage, abortion and sepsis. However, country or regional differences in the relative magnitudes of specific causes of adolescent maternal mortality and

hypertensive disorders were found to be a more important cause of mortality for adolescents (10).

In this study, we aimed to introduce and perform an applied methodological study in clinical epidemiology to determine the main causes of maternal mortality in Fars province, south of Iran in 2014, using Root-cause analysis (RCA). Therefore, in addition to recognizing the possible faults in maternal mortality, the main and final causes will be identified. Obviously, identifying the main causes of maternal mortality is an effective step towards preventing the recurrence of deficiencies and risk factors associated with maternal mortality. These factors are further important for adopting policies needed to care for pregnant women.

Data source: The data were collected from: 1) Death registration system, 2) Maternal mortality surveillance system, and 3) Verbal-autopsy.

Materials and methods

This case-series study aimed to describe the main causes of maternal mortality. For data analysis, RCA was used as the analytic method, which is used as a technique in clinical epidemiology. RCA is part of improving the safety and quality in the strategic management of clinical governance in hospitals and health centers. To this end, comprehensive information about maternal mortality cases was gathered, then RCA was performed using the following steps:

1. Organizing and formatting a committee of experts with clinical knowledge in the field and skillful interdisciplinary research,
2. Drawing the fishbone of main risk factors,
3. Weight the main cause of maternal death by the expert committee,
4. Designing dynamic modeling and quantifying the qualitative data through drawing Bayesian belief networks (BBNs), and
5. Performing sensitivity analysis to determine the magnitude of contribution of each root-cause of maternal mortality.

Netica-5.18 software was used to quantify the qualified data, analyze them and make a dynamic model. Drawing BBNs based on conditional probabilities can display the overall impacts of different causes on maternal mortality in the form of quantitative dynamic modeling. Quantitative dynamic modeling and sensitivity analysis were done to specify the main factors and the root-causes of maternal deaths.

In quantitative dynamic modeling, each effective cause is depicted as a node; the relationship between these nodes are displayed based on the type of interaction between nodes. Each node of the bar graph represents the percentage of effectiveness and

ineffectiveness on the outcome.

Sensitivity analysis was done to determine the contribution of the magnitude effect of each main cause and definitive diagnosis root-causes of maternal mortality. Results were produced in three columns as follows:

A. Mutual Info: each node shares an amount of data with the outcome node which displays the influence of each node on the outcome node. This level of influence was called *interaction*.

B. Percent of Impact: which reveals the percentage and power of each node's influence on the outcome node. These are the final criteria to determine the root-causes of maternal mortality. In this method each node is sorted based on the percentage of its impact and the first node after the outcome node would be the root-cause of maternal mortality.

C. Variance of beliefs: which displays the amount of distribution of each node around the outcome node in Bayesian Belief Networks (BBNs).

Quantitative dynamic modeling along with sensitivity analysis was conducted for case no. 1 that as shown in the result section, and for other cases have been brought in the supplement section.

This study was approved by the Ethics Committee of Shiraz University of Medical Sciences with code number IR.SUMS.REC.1394.S788.

Results

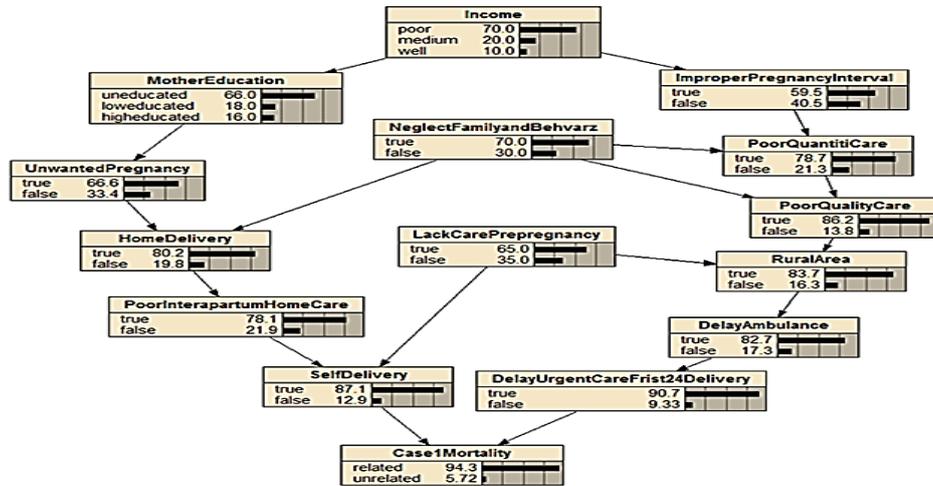
In 2014, 10 maternal deaths occurred in Fars province, south of Iran with MMR=13.4 per 100,000 birth. Among all maternal deaths, generally 70% were postpartum and 30% occurred before delivery.

The causes of maternal deaths reported by the health system included: 10% postpartum hemorrhage, 20% eclampsia and preeclampsia, 10% amniotic fluid embolism, 20% of infection and Disseminated intravascular coagulation (DIC), 10% of suicides, 10% ectopic pregnancy, 10% thrombotic thrombocytopenic purpura (TTP), and 10% were unknown. However, our results showed that the root-cause of all deaths using RCA were: 10% delays in service delivery in the first 24 hours after childbirth, 10% unsatisfactory quality and quantity of care, 30% delay in or failure to diagnose, and 50% neglect and negligence (Table 1).

According to figure 1A, case no.1 who was a 23-year-old mother which lived in a rural area, was investigated with respect to family income, living area, education level, pregnancy interval, health care quality and quantity, pregnancy planning, family support, delivery place, delivery agent, ambulance services and hospital emergency cares. Reason of death reported by health system was postpartum hemorrhage. However, Using the RCA method and placing the set of factors influencing maternal death in the modeling resulted from the drawing of the Bayesian belief networks (BBNs) in the output of Netica software, the percentage of the impact of each of the causes was shown as a node in the modeling. Finally, by sensitivity analysis (Figure 1B), the contribution of the effect of influential causes was determined and identified; delay in providing urgent care in the first 24 hours after delivery as a root-cause of maternal death had a contribution of 26.4% than other causes in case no.1.

Table 1: The Causes of Maternal Death Reported by The Health System and Root-Causes of Maternal Death Using RCA

Case number	Age of mother (years)	cause of deaths reported before using RCA	Root-causes of maternal death using RCA
(1)	23	Postpartum hemorrhage	Delay in urgent care in the first 24 hours after delivery
(2)	34	Preeclampsia	Neglect and negligence in therapeutic interventions to control hypertension during pregnancy
(3)	40	Amniotic fluid embolism (AFE)	Negligence and unacceptable care during delivery (No attention to vital signs and not providing proper care during childbirth)
(4)	30	Disseminated intravascular coagulation(DIC)	Lack of clinical diagnosis to effectively follow-up disseminated infections during pregnancy (DIC)
(5)	28	Suicide with pills rice	Neglect in terms of mother's postpartum depression and more likely to commit suicide
(6)	27	Unknown	Neglect of medical and psychiatric team work treatment in the pursuit of active to clinical and mental problems (disseminated infections)
(7)	38	Eclampsia (ICH)	Poor quality and quantity of care during pregnancy (ICH)
(8)	33	Thrombotic thrombocytopenic purpura (TTP)	Neglecting interventions for abortion and termination of pregnancy in the first few months of pregnancy (TTP)
(9)	20	Ectopic pregnancy (EP)	Delay in diagnosis of internal bleeding and ectopic pregnancy (EP)
(10)	25	Sepsis and DIC	Lack of perform laparotomy for proper diagnosis and immediate treatment of sepsis published and control DIC



Sensitivity of 'Case1Mortality' to a finding at another node:

Node	Mutual Info	Percent	Variance of Beliefs
Case1Mortality	0.31623	100	0.0539293
DelayUrgentCareFrist24De	0.08362	26.4	0.0114616
SelfDelivery	0.02597	8.21	0.0027673
DelayAmbulance	0.01342	4.24	0.0012498
RuralArea	0.00319	1.01	0.0002725
PoorInterpartumHomeCare	0.00206	0.651	0.0001669
LackCarePrepregnancy	0.00116	0.368	0.0000894
HomeDelivery	0.00027	0.0847	0.0000207
PoorQualityCare	0.00013	0.0414	0.0000101
NeglectFamilyandBehvarz	0.00005	0.0157	0.0000037
PoorQuantitiCare	0.00002	0.00546	0.0000013
UnwantedPregnancy	0.00000	0.00148	0.0000004
MotherEducation	0.00000	0.000274	0.0000001
Income	0.00000	7.59e-05	0.0000000
ImproperPregnancyInterva	0.00000	6.32e-05	0.0000000

Figure 1: (A) Modeling of Case no.1: 23 years old, dynamic modeling of the main causes of maternal death, (B) Sensitivity analysis of Case no.1: Root-cause of death: Delay in providing urgent care in the first 24 hours after delivery, contribution of magnitude effect =26.4%

For other cases, Quantitative dynamic modeling along with sensitivity analysis have been brought in the RCA modeling – supplement section.

Discussion

Using the RCA method, the main causes of maternal mortality in Fars province, south of Iran in 2014 were investigated, and RCA determined the underlying causes of maternal deaths.

We found that almost all of the causes of maternal death reported by the health system were preventable. Also after applying and performing RCA, it was observed that neglect and negligence were the most common root-causes of maternal mortality.

In all maternal deaths neglect and negligence, as main root-cause occurred in 30% of cases before pregnancy, 70% of cases during pregnancy, 30% of

cases during childbirth and 50% of cases in the first 24 hours after childbirth (increase of more than 100% because of overlapping negligence in various stages of pregnancy).

Results of sensitivity analysis conducted for each maternal death confirmed that factors such as neglect and negligence, lack of timely decision making, delay or failure in proper diagnosis, and delay in providing immediate medical care as well as lack of health care, were the main root-causes of maternal mortality.

Maternal mortality rates increased by 90% for women ≥ 40 , also for non-specific causes of death increased by 48%; however, the rate for specific causes of death did not increase significantly between 2008–2009 (13.5) and 2013–2014 (15.0) (11). 99% of maternal deaths occur in developing countries (12). Direct causes resulting from interference, negligence,

inappropriate treatment or chain of events which are associated with pregnancy and childbirth. In developing countries, direct causes responsible for 75-80% of maternal mortality, often include bleeding, sepsis and maternal hypertension. In developed countries, indirect causes are the main causes of maternal mortality among which thromboembolism accounts for a higher percentage than any other cause (13, 14). Three delay causes of maternal mortality including: Delay in making the decision to provide care, delay in transferring the pregnant woman to a place with medical facilities, and delay in providing medical facilities after transferring the mother to the health center (15, 16). In Africa and Asia, bleeding is the leading cause of maternal mortality (30.8-33.9%). Next in rank are the problems caused by high blood pressure (9.7%) (17). The most common cause of maternal death in the first 3 months of pregnancy in the United States was ectopic pregnancy and its complications. While the incidence of ectopic pregnancy has increased in recent years, a 90% reduction in mortality. This significant reduction is the result of early diagnosis and appropriate treatment measures immediately after the diagnosis of ectopic pregnancy (18, 19). Nearly 50% of maternal deaths due to pulmonary embolism occur in the first 24 hours after delivery. Also, 68% of deaths caused by bleeding occur in the first 48 hours after delivery. Cardiomyopathy is one of the major causes of maternal mortality and it occurs during 43 to 365 days after delivery in 45% of cases. The risk of mortality in women above 39 years of age is five times greater than that in younger women (20). The significant effect of using RCA method in identifying the root causes of the major risk factors in medical sciences is specified. Using this analytical method in identifying major risk factors allows correct planning necessary to manage the consequences (21). Amongst the 29 studies published between 2003 and 2017 in Iran, a total of 69.9%, 20.6%, and 5.2% of the mortalities were due to direct, indirect and unspecified causes respectively and 4.3% of the causes were not clear in several studies. The leading direct and indirect causes of death were identified as hemorrhage (30.7%) and hypertensive disorders (17.1%) and circulatory system diseases (8.1%) respectively and Several factors including gravidity, type of delivery, socio-economic status of mothers, locations of birth, death and maternity care venues were found in the original studies as the most important determinant of maternal mortalities in Iran

(22). RCA method was used to determine main and root cause of another unfortunate events, including: investigate the causes of 218 pancreatic cancer induced deaths of 36 surgeons in 4 countries, examining the death of a 13 years old boy during maxillofacial plastic oral surgery, the leading causes of death in liver transplant patients, the main causes of crashes resulting in injury of psychiatric patients (23, 24, 25, 26). RCA method was performed in two hospitals of England on the subject of policy and practice to investigate adverse clinical events. The results showed that the gap between theories and their implementation at the community level, will be effective only if approach contradictions were modified and programs are implemented properly after correct understanding the community facts and otherwise it will have a negative impact on patient care system (27).

A few studies have analyzed the root-causes of maternal mortality. Similar to our results they have also recognized: service providers' negligence, lack of timely prevention of risk factors and diseases identification and diagnosis, lack of inter-sectorial coordination, lack of attention to health care, lack of timely provision of health care needed, and lack of adequate access to facilities as the root-causes.

This study also analyzed the mentioned root-causes of maternal mortality and showed that most causes can be modified and controlled in health systems and it is possible to prevent, control and reduce maternal mortality by proper use of guidelines developed to provide health care and emergency medical services at the appropriate time before pregnancy, during pregnancy, during delivery, and after delivery. Moreover, paying attention to social determinants of health (SDH) as valuable factors in maternal health management has a predominant role in the prevention of maternal mortality.

This study had several limitations such as the lack of necessary information in some health records and treatment files for a more accurate assessment of the causes of maternal mortality, lack of cooperation by some families with the research team and the lack of adequate notice of the effective factors in maternal deaths. Moreover, long distance of some households to complete questionnaires and verbal autopsy also complicated the study.

Conclusion

Not only RCA determined the main cause/causes of maternal mortality but also it showed that the

obtained root causes are preventable and also they can be controlled and modified by targeted training and increasing facilities, particularly in remote areas. Therefore, it is recommended to provide guidelines and training for all levels of service providers, identify and diagnose risk factors and diseases in time, coordination between different levels of service providers, pay attention to providing on time appropriate health care before pregnancy, during pregnancy and postpartum, provide and improve the standard equipment and access to facilities, and provide urgent medical services and timely follow-up care according to maternal surveillance system, based on the root causes of maternal mortality in order to prevent and reduce maternal deaths.

Suggestions: After doing this research project the following measures were proposed in order to organize, control and reduce maternal mortality:

1. Arranging team-rounds for high-risk pregnant mothers in hospitals.
2. Arranging Mother's bleeding control team in hospitals.
3. Constant prenatal and postpartum care monitoring based on the protocol integrated by surveillance system
4. To increase family knowledge about the complications of pregnancy and childbirth and about how to deal with them.
5. Providing mothers with timely care, urgent services and timely diagnosis of risk symptoms affecting maternal mortality.
6. Making quick and correct decision about referring high-risk pregnant women.

To equip hospitals with adequate personnel and emergency obstetric supplies.

Conflict of Interests

Authors have no conflict of interests.

Acknowledgments

We are grateful to professor Tabatabai, Faculty Member of Department of Epidemiology, Shiraz High Institute of Health, for his administrative and statistical advice. We appreciate Dr. A. Hemmati. Rasoul, executive Vice-chancellor of health center in Fars province for his supports. We would like to thank Dr. Goudarzi. Forough, Biodiversity Dr. of Isfahn University - whose significant statistical tips contributed a great deal to this research. We would like to thank the maternal health expert of Fars health center, Ms. Hesami Elham, who helped manage

documents and collect data and Ms. DarrehShurzadeh Mandana, maternal health expert of Fars health center who helped collect required documents, as well as all maternal health experts of Fars healthcare networks who helped us collect the required information.

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Citation: Mirahmadizadeh A, Semati A, Eshrati B, Moradi F, Asadi N. **Root-Cause Analysis of Maternal Mortality in Fars Province, Southern Iran 2014: Negligence Is the Prime Suspect.** *J Fam Reprod Health* 2020; 14(3): 166-72.