Database Autopsy: An Efficient and Effective Confidential Enquiry into Maternal Deaths in Canada

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ABSTRACT

Background: Maternal death surveillance in Canada relies on hospitalization data, which lacks information on the underlying cause of death. We developed a method for identifying underlying causes of maternal death, and quantified the frequency of maternal death by cause.

Methods: We used data from the Discharge Abstract Database for fiscal years 2013 to 2017 to identify women who died in Canadian hospitals (excluding Quebec) while pregnant or within 1 year of the end of pregnancy. A sequential narrative based on hospital admission(s) during and after pregnancy was constituted and reviewed to assign the underlying cause of death (based on the World Health Organization's framework). Maternal deaths (i.e., while pregnant or within 42 days after the end of pregnancy) and late maternal deaths (i.e., more than 42 days to a year after the end of pregnancy) were examined separately.

Results: We identified 85 maternal deaths. Direct obstetric causes included 8 deaths (9%) related to complications of spontaneous or induced abortion; 9 (11%), to hypertensive disorders of pregnancy; 15 (18%), to obstetric hemorrhage; 11 (13%), to pregnancy-related infection; 16 (19%), to other obstetric complications; and <5 (<6%), to complications of management. There were 21 (25%) maternal deaths with indirect obstetric causes, and <5 (<6%) with undetermined causes. Of 120 late maternal deaths, 16 (13%) had direct obstetric causes, among them, 9 deaths by suicide (56%). One hundred late maternal deaths (83%) had indirect obstetric causes; and <5 (<4%) had undetermined causes.

Conclusions: The majority of maternal deaths in Canada have direct obstetric causes, whereas most late maternal deaths have indirect obstetric causes. Suicide is an important direct cause of late maternal death.

Keywords: maternal mortality; cause of death; public health surveillance; epidemiology; methods

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Résumé

Objectif : Au Canada, la surveillance de la mortalité maternelle repose sur les données d'hospitalisation, lesquelles ne contiennent pas d'information ou de champs spécifique sur les causes de décès. Nous avons mis au point une méthode pour déterminer les causes sous-jacentes des cas de mortalité maternelle. Nous avons aussi calculé la fréquence de mortalité maternelle selon la cause.

Méthodolgie : Nous avons utilisé les données de la Base de données sur les congés des patients pour les exercices financiers de 2013 à 2017 afin de déterminer le nombre de femmes qui sont décédées pendant la grossesse ou dans l'année suivant la fin de la grossesse dans un hôpital canadien (excluant le Québec). Une séquence narrative a été constituée d'après la ou les hospitalisations pendant et après la grossesse. Cette séquence a été examinée afin d'attribuer la cause sous-jacente du décès (d'après le cadre de l'Organisation mondiale de la Santé). La mortalité maternelle (c.-à-d. pendant la grossesse ou dans les 42 jours suivant la fin de la grossesse) a été examinée séparément de la mortalité

maternelle tardive (c.-à-d. plus de 42 jours à un an après la fin de la grossesse).

Résultats : Nous avons dénombré 85 cas de mortalité maternelle. Les causes obstétricales directes comprenaient 8 décès (9 %) liés à des complications d'uneavortement spontané ou d'uneinterruption volontaire de grossesse; 9 (11 %), à l'hypertension gravidique; 15 (18 %), à l'hémorragie obstétricale; 11 (13 %), à une infection relative à la grossesse; 16 (19 %), à d'autres complications obstétricales; et < 5 (< 6 %), à la prise en charge des complications. Il y a eu 21 cas de mortalité maternelle (25 %) de cause obstétricale indirecte et < 5 cas (< 6 %) de cause indéterminée. Parmi 120 cas de mortalité maternelle tardive, 16 (13 %) étaient de cause obstétricale directe, dont 9 décès par suicide (56 %). Des cas de mortalité maternelle tardive, 100 (83 %) étaient de cause obstétricale indirecte et < 5 (< 4 %) étaient de cause indéterminée.

Conclusions : Au Canada, la majorité des cas de mortalité maternelle ont des causes obstétricales directes, tandis que les cas de mortalité maternelle tardive sont généralement de cause obstétricale indirecte. Le suicide est une importante cause directe de mortalité maternelle tardive.

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INTRODUCTION

Maternal death is a rare complication of childbearing in most high-income countries. From 1999 to 2015, pregnancy-related deaths rates in Canada ranged from five to 12 per 100 000 hospital deliveries.[1] However, maternal deaths occur at disproportionately high rates in vulnerable populations.[1–6] Such disparities in maternal mortality among subpopulations are a serious concern, and prevention of maternal deaths has received increasing emphasis in Canada in recent years.

For the last several years, surveillance of maternal deaths in Canada has relied on hospitalization data from the Discharge Abstract Database of the Canadian Institute for Health Information. This is because such hospital data provide more accurate estimates of maternal mortality rates than information from Statistics Canada's death registration database.[1,7,8] However, one significant limitation of maternal mortality surveillance based on hospitalization data is the lack of information on the underlying cause of death, defined as "the disease or condition that initiated the morbid chain of events leading to death or the circumstances of the accident or violence that produced a fatal injury."[9] Population information on underlying causes of death serves as a critical input for developing preventive and public health programs.

A confidential enquiry into maternal deaths, such as that implemented in the United Kingdom and Ireland,[10] could shed light on the underlying causes of maternal death, the proportion of preventable deaths, and the critical steps that can be taken to improve maternal health and care processes. However, there are several challenges to be overcome before a national confidential enquiry into maternal deaths can be instituted in Canada (including medicolegal and privacy issues, and data-sharing across provinces/territories).[11–13] Meanwhile, the lack of information on underlying causes of maternal death represents a glaring weakness in national maternal health surveillance, as evidenced by the fact that the most recent detailed report with information on the underlying causes of maternal death involved deaths that occurred over 20 years ago, between 1997 and 2000.[14]

We attempted to address this information gap by using national hospitalization records to create a sequential narrative for identifying the underlying causes of maternal death. Timely information obtained through such a process could provide preliminary direction for clinical and public health initiatives to prevent maternal deaths in Canada.

METHODS

The study was based on a review of maternal deaths in Canada (excluding Québec) using information from the Discharge Abstract Database of the Canadian Institute for Health Information for the fiscal years 2013–2017 (April 2013 to March 2018). It relied on a careful examination of all information available in the database for each identified patient, a method we refer to as a "database autopsy."

Data Source

Discharge Abstract Database records included up to 25 diagnosis variables (coded using the International Statistical Classification of Diseases and Related Health Problems, 10th revision, Canadian version [ICD-10-CA]) and up to 20 intervention codes based on the Canadian Classification of Health Interventions (CCI), with the date, timing, and location of each intervention specified.[15-17]

Eligibility

We first identified women whose hospitalization records included a diagnosis code for pregnancy, childbirth, or a puerperal condition using obstetric codes (ICD-10-CA code: O.^^) or codes for an encounter with obstetric health services (ICD-10-CA code: Z32.1, Z33-Z37, Z39). Women with codes for delivery-related interventions (CCI code: 5.

MD.5^.^^, 5.MD.60.^^) were also identified. Provincial identification numbers and hospital chart numbers (both scrambled to maintain anonymity) were then used to deterministically link all hospital records of women of reproductive age who died in the hospital with those who had an obstetric-related hospitalization in the year before death.

Underlying Causes of Death

All variables in the hospitalization record(s) were used to create a vignette for each woman describing the circumstances of the death as documented in the Discharge Abstract Database (see online Appendix 1 for fictional examples). The vignettes were then used by a reviewer (A.B.) to identify the underlying cause of death based on the temporal sequence of events and the method for determining the underlying cause of death as described by the World Health Organization (WHO).[9] Uncertain cases were resolved after discussion with a second reviewer (K.S.J.). The underlying causes of death were then categorized according to the framework developed by the WHO Working Group on Maternal Mortality and Morbidity Classification with ICD-10 codes.[9] This classification included nine underlying cause-of-death categories (the first six represent direct obstetric causes): (1) pregnancy with abortive outcome (e.g., complication after spontaneous abortion, medical nonsurgical or surgical abortion); (2) hypertensive disorders in pregnancy, childbirth, and the puerperium; (3) obstetric hemorrhage; (4) pregnancy-related infection; (5) other obstetric complications (e.g., obstetric blood clot embolism); (6) unanticipated complications of management (e.g., complications of anesthesia); (7) indirect obstetric causes (i.e., a previously existing disease or a disease that may have developed during pregnancy but was not related to direct obstetric causes and could have been aggravated by the physiologic effects of pregnancy, e.g., malignancy); (8) unknown/undetermined causes; and (9) coincidental causes (e.g., motor vehicle accident). We considered deaths due to accidental poisoning with cocaine or opioids as deaths due to drug addiction (classified as an indirect cause of death, rather than a coincidental cause).

Deaths were referred to as "maternal deaths" if they occurred during pregnancy or within 42 days of the end of pregnancy and as "late maternal deaths" if they occurred more than 42 days and less than 1 year after the end of pregnancy. Coincidental deaths were reported but not included in the maternal death and late maternal death counts.

Characteristics of Maternal Deaths and Contributory Conditions

We analyzed information on the province of residence, rural residence (based on the first three characters of the postal code of maternal residence), and age at death. We also quantified the frequency of deaths with associated diagnoses of mental and behavioural disorders or substance use at any hospitalization during pregnancy or within a year before death (ICD-10-CA codes provided in online Appendix 2). Additional diagnoses regarding "contributory conditions not likely to cause death" were identified based on ICD-10-CA codes at the time of delivery and a list of such conditions published by the WHO.[9] We reported contributory conditions that were observed in at least five cases.

Analysis

The frequency of each cause-of-death category and of specific underlying causes of death were quantified. Cell counts under five were not reported to ensure confidentiality. Maternal mortality ratios (expressed per 100 000 live births) were estimated by dividing the number of direct and indirect obstetric deaths by the number of live births reported by Statistics Canada for calendar years 2013–2017 (excluding Québec).[18] The maternal mortality rate per 100 000 hospital deliveries was based on the number of hospital deliveries in the Discharge Abstract Database for fiscal years 2013–2017.

Interobserver Agreement

Twenty-five vignettes were randomly selected for re-examination by a third reviewer with maternal-fetal medicine expertise (J.L.) who independently determined the underlying cause of death using the same vignettes and process described. The interobserver agreement for determining the underlying cause of maternal death using the database autopsy method was estimated using the proportion of agreement and kappa coefficient.

RESULTS

For the 5-year period, 228 deaths were identified as potentially eligible, of which 3 were excluded owing to suspected coding errors (online Appendix 3). Thus, there were 225 deaths among women during pregnancy or within 1 year of the end of pregnancy: 81 due to direct obstetric causes, 125 due to indirect obstetric causes, eight due to undetermined cause (Table 1), and 11 due to coincidental causes. The distribution of maternal deaths from direct and indirect causes by province/territory is presented in Table 2.

Maternal Deaths

We identified 85 maternal deaths, of which eight (9%) were classified as being due to abortive outcomes; nine (11%) to hypertensive disorders in pregnancy, childbirth, and the puerperium; 15 (18%) to obstetric hemorrhage; 11 (13%)

Table 1. Number and rates of maternal death during or after pregnancy, by timing of death in relation to the end of pregnancy (Canada, excluding Québec; 2013–2017)

Timing	All maternal deaths[a]			Direct maternal deaths			Indirect maternal deaths		
	No.	Ratio per 100 000 live births	Rate per 100 000 hospital deliveries	No.	Ratio per 100 000 live births	Rate per 100 000 hospital deliveries	No.	Ratio per 100 000 live births	Rate per 100 000 hospital deliveries
Maternal deaths (during pregnancy or within 42 d of the end of pregnancy)	85	4.5	6.0	60	3.1	4.2	21	1.1	1.5
Late maternal deaths (from >42 d to 1 y after the end of pregnancy)	120	6.3	8.4	16	0.8	1.1	100	5.2	7.0
Total[b]	214	11.2	15.0	81	4.2	5.7	125	6.6	8.8

[a] Includes eight women with an undetermined cause of death during pregnancy or within 42 days of the end of pregnancy but does not include deaths due to coincidental causes.

[b] Includes nine women who died from direct or indirect causes for whom the available information was insufficient to determine the time elapsed from the end of pregnancy.

to pregnancy-related infection; 16 (19%) to other obstetric complications; fewer than five (<6%) to complications of management; 21 (25%) to indirect obstetric causes; and fewer than five (<6%) to undetermined causes (Table 3).

Late Maternal Deaths

There were 120 late maternal deaths, of which 16 (13%) were due to direct obstetric causes (including nine [56%] deaths by suicide). There were 100 deaths (83%) due to indirect obstetric causes (including 46 [46%] related to malignancy; 21 [21%] related to diseases of the circulatory system, such as tricuspid valve disease and nonobstetric pulmonary embolism; and 12 (12%) related to drug addiction [accidental poisoning after exposure to cocaine, opioids, etc.]). Fewer than five late maternal deaths (<4%) were due to undetermined causes.

Nine women died from direct or indirect obstetric causes within a year of a hospital admission that included a diagnostic code indicating the end of a pregnancy (e.g., a spontaneous abortion, a medical abortion, or a postpartum diagnostic code), but the information available was insufficient to determine the time elapsed from the end of pregnancy to death (Table 1).

Maternal mortality ratios for specific underlying causes of death are shown in the Figure. Characteristics of direct and indirect obstetric deaths and contributory conditions are reported in Tables 4 and 5, respectively. Maternal mortality rates per 100 000 hospital deliveries (direct, indirect, and undetermined causes combined) varied significantly with age ($P < 0.001$), parity ($P < 0.001$), and rural residence ($P = 0.005$).

Interobserver Agreement

Of the 25 randomly selected vignettes, both reviewers identified the same underlying cause of death in 21 cases (84%) and the same WHO cause-of-death category in 24 cases (96%). The kappa coefficient for cause-of-death category was 0.94 (95% confidence interval 0.71−1.00). Differences between reviewers were mostly minor (online Appendix 4).

DISCUSSION

Hospitalization record−based vignettes provided a reasonable clinical picture that permitted identification of an underlying cause of maternal death in most cases. Although this "database autopsy" cannot match a definitive maternal mortality review based on medical charts and related information in terms of accuracy and detail, this innovative method does permit a quick and effective tabulation of the principal underlying causes of in-hospital

Table 2. Maternal deaths during pregnancy or up to 1 year after the end of pregnancy and maternal mortality ratios per 100 000 live births and maternal mortality rates per 100 000 hospital deliveries for direct and indirect causes of deaths (Canada, excluding Québec; 2013–2017)

	Direct maternal deaths			Indirect maternal deaths		
Region	No.	Ratio per 100 000 live births	Rate per 100 000 hospital deliveries	No.	Ratio per 100 000 live births	Rate per 100 000 hospital deliveries
Canada	81	4.2	5.7	125	6.6	8.8
British Columbia	8	3.6	3.8	16	7.2	7.6
Alberta	17	6.2	6.5	19	6.9	7.2
Saskatchewan	7	9.1	9.2	10	13.0	13.2
Manitoba	5	6.0	6.0	16	19.1[a]	19.1[a]
Ontario	40	5.7[b]	5.9	59	8.4[b]	8.7
Atlantic provinces	<5	<4.8	<4.9	5	4.8	4.9[b,c]
Combined Territories[d]	<5	<53.1	<66.4	<5	<53.1	<66.4

[a] Significantly different from the rest of Canada ($P < 0.05$).

[b] P values between 0.05 and 0.10.

[c] The indirect mortality rate per 100 000 hospital deliveries in Atlantic provinces combined as well as New Brunswick alone are <8.8 per 100 000 hospital deliveries. The P values for the other Atlantic provinces individually were >0.10.

[d] Combined territories include the Northwest territories, Nunavut, and the Yukon.

Table 3. Number and rates of deaths during pregnancy or within 1 year of the end of pregnancy (per 100 000 hospital deliveries) by underlying cause of death (Canada, excluding Québec; 2013–2017)

	All deaths; n = 225		Maternal deaths[a]; n = 85		Late maternal deaths[b]; n = 120	
Underlying cause of death categories	No. (%)	Rate per 100 000 deliveries	No. (%)	Rate per 100 000 deliveries	No. (%)	Rate per 100 000 deliveries
Direct maternal deaths						
Group 1: Pregnancy with abortive outcome	10 (4.4)	0.70	8 (9.4)	0.56	0	0
Group 2: Hypertensive disorders	9 (4.0)	0.63	9 (10.6)	0.63	0	0
Group 3: Obstetric hemorrhage	15 (6.7)	1.05	15 (17.6)	1.05	0	0
Group 4: Pregnancy-related infection	13 (5.8)	0.91	11 (12.9)	0.77	<5 (<4.2)	<0.35
Group 5: Other obstetric complications[c]	32 (14.2)	2.24	16 (18.8)	1.12	14 (11.7)	0.98
Group 6: Complications of management[d]	<5 (<2.2)	<0.35	<5 (<5.9)	<0.35	<5 (<4.2)	<0.35
Indirect maternal deaths						
Group 7: Nonobstetric complications[e]	125 (55.6)	8.76	21 (24.7)	1.47	100 (83.3)	7.01
Other deaths						
Group 8: Undetermined	8 (3.6)	0.56	<5 (<5.9)	<0.35	<5 (<4.2)	<0.35
Group 9: Coincidental causes[f]	11 (4.9)	0.77	—	—	—	—

[a] During pregnancy or within 42 days of the end of pregnancy.

[b] More than 42 days to 1 year after the end of pregnancy.

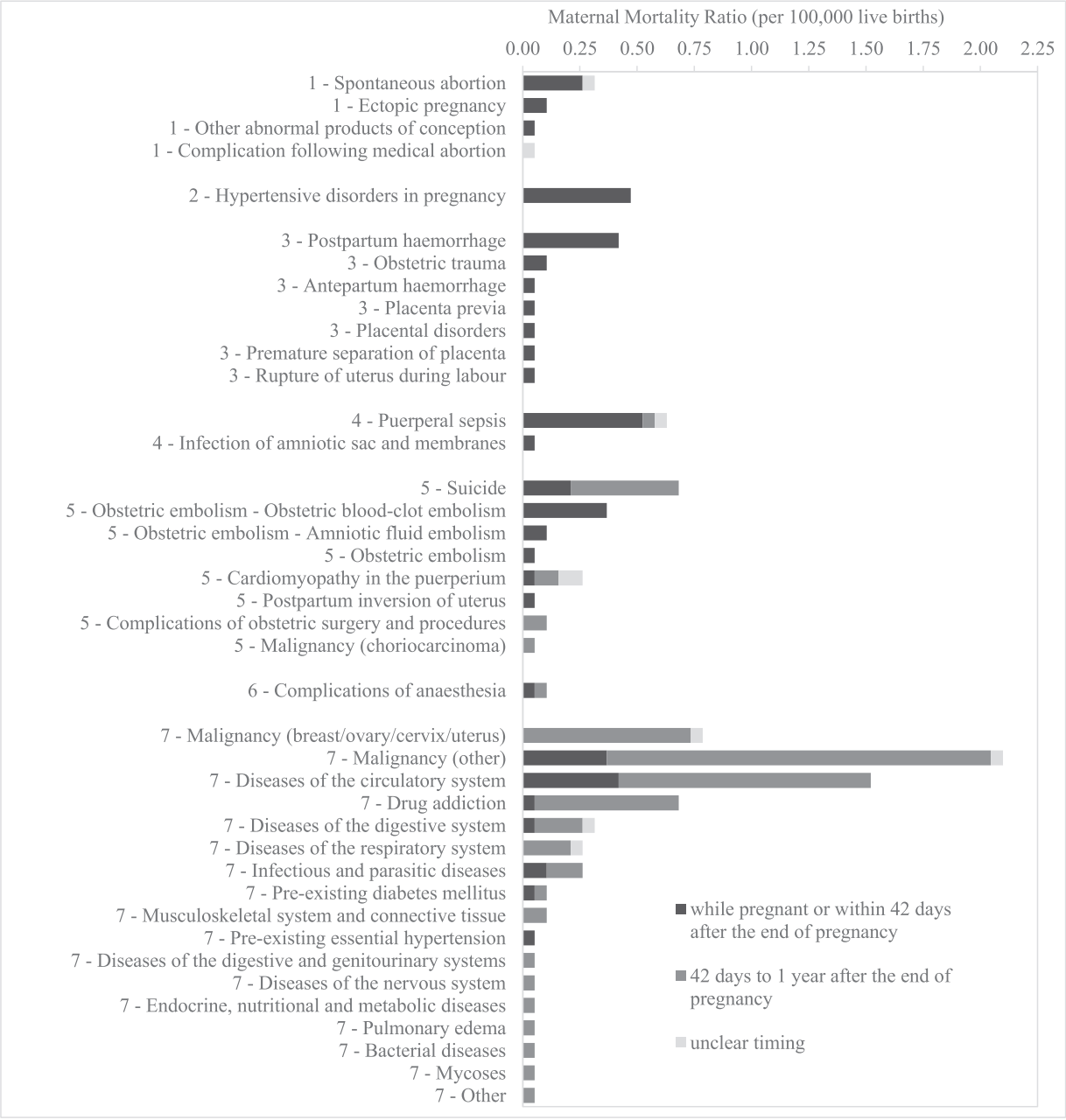
[c] Other obstetric complications included obstetric blood clot embolism, amniotic fluid embolism, intentional self-harm (death by suicide), complications of obstetric surgery and procedures (such as disruption of cesarean section wound, cardiomyopathy, and other complications of the puerperium).

[d] "Complications of management" refers to anesthetic complications.

[e] Nonobstetric complications included malignancies; diseases of the circulatory system, digestive system, respiratory system, nervous system, musculoskeletal system; drug addiction; and so on.

[f] Coincidental causes included trauma from falls and motor vehicle accidents; toxic effect of exposure to gases, fumes, and vapours; misadventures during surgical and medical care (e.g., anaphylactic shock); and accidental poisoning unrelated to substance use. Deaths due to coincidental causes were not included in the maternal deaths count.

Figure. Maternal mortality ratios by underlying cause of maternal death, Canada (excluding Québec), 2013–2017. Numbers before labels indicate the World Health Organization underlying-cause-of-death category.



maternal deaths in Canada. It shows that a majority of maternal deaths in Canada in the study period were due to obstetric hemorrhage, pregnancy-related infections, hypertensive disorders of pregnancy, and other complications such as obstetric embolism.

For calendar years 2013–2017, Statistics Canada reported 94 direct and 23 indirect obstetric deaths among women who were pregnant or within a year of pregnancy, with annual maternal mortality ratios ranging from 4.4 to 5.3 per 100 000 live births for direct obstetric deaths and from 0.8 to 1.8 per 100 000 live births for indirect obstetric deaths.[19] Our estimated maternal mortality ratio for direct obstetric deaths (including late maternal deaths) was slightly lower (4.2 per 100 000 live births), although our maternal mortality ratio for indirect causes was higher (6.6 per 100 000 live births). The latter difference was primarily due to our improved identification of late, indirect maternal deaths. On the other hand, Statistics Canada's report on specific causes of death highlights potential disease

Table 4. Characteristics of maternal deaths during pregnancy or within 1 year of the end of pregnancy (Canada, excluding Québec; 2013–2017)

Characteristics	Direct maternal deaths, no. (%); n = 81	Rate per 100 000 hospital deliveries	χ^2 *P* value	Indirect maternal deaths, no. (%); n = 125	Rate per 100 000 hospital deliveries	χ^2 *P* value
Age, y			0.049			<0.001
15–19	<5 (<6.2)	<12.6		<5 (<4.0)	<12.6	
20–24	10 (12.3)	5.6		18 (14.4)	10.1	
25–29	19 (23.5)	4.7		22 (17.6)	5.5	
30–34	25 (30.9)	5.0		37 (29.6)	7.4	
35–39	18 (22.2)	7.2		28 (22.4)	11.1	
40–44	7 (8.6)	13.8		12 (9.6)	23.6	
45–49	<5 (<6.2)	<166.8		<5 (<4.0)	<166.8	
Parity			0.09			<0.001
0	20 (24.7)	3.6		38 (30.4)	6.8	
1-2	24 (29.6)	3.8		37 (29.6)	5.8	
≥3	9 (11.1)	8.1		21 (16.8)	18.9	
Missing	28 (34.6)	—		29 (23.2)	—	
Rural residence			0.10			0.010
Yes	18 (22.2)	7.8		30 (24.0)	13.0	
No	60 (74.1)	5.1		91 (72.8)	7.7	
Missing	<5 (<6.2)	—		<5 (<4.0)	—	

pathways that are more likely to lead to an out-of-hospital death, which would have been missed in our study. For example, Statistics Canada reported 21 deaths due to obstetric embolism from January 2013 to December 2017, whereas we identified 10 deaths from obstetric embolism from April 2013 to March 2018. Although the difference between these counts could have occurred partly because of the inclusion of Québec data in the Statistics Canada report, it is likely that we failed to identify a small number of cases of out-of-hospital maternal deaths due to obstetric embolism.

The previous detailed Canadian report on maternal deaths between 1997 and 2000 yielded a direct maternal mortality ratio of 4.2 and an indirect maternal mortality ratio of 1.9 per 100 000 live births[14] (vs. a direct mortality ratio of 3.1 and an indirect mortality ratio of 1.1 per 100 000 live births for maternal deaths from 2013 to 2017). Some time period differences, such as those with regard to direct causes, are noteworthy: In 1997–2000, the main direct causes of death included pulmonary embolism, pre-eclampsia and other hypertensive disorders, and amniotic fluid embolism, whereas in 2013–2017, the principal direct causes of maternal death were puerperal sepsis, hypertensive disorders of pregnancy, postpartum haemorrhage, and obstetric blood clot embolism (i.e., pulmonary embolism). The large contribution of puerperal sepsis to maternal mortality in recent years requires close scrutiny, especially because severe maternal morbidity due to sepsis has decreased substantially, from 17.2 in 2003 to 8.6 per 10 000 deliveries in 2016 in Canada.[20] It is noteworthy that 46% of deaths due to pregnancy-related infections occurred at readmission after delivery.

Furthermore, death by suicide was the most important direct cause of late maternal deaths in 2013–2017. The high frequency of mental and behavioural disorders and substance use observed among cases of maternal death also highlights potential disparities in perinatal health and may indicate missed prevention opportunities in the antenatal and postpartum periods for vulnerable populations.

We observed variation in maternal mortality ratios between provinces. Moreover, women with a rural residence were overrepresented among maternal deaths (23% of deaths vs. 16% of women delivering in Canadian hospitals in 2013–2017). Although differences in maternal characteristics likely explain some of the regional variations in maternal mortality and differences by rural versus urban residence location, issues related to perinatal health care access and equity also need to be further examined and addressed.

Table 5. Contributory conditions at last delivery and other characteristics among maternal deaths during pregnancy or within 1 year of the end of pregnancy (Canada, excluding Québec; 2013–2017)

Conditions and characteristics	No. (%)	
	Direct maternal deaths; n = 81	Indirect maternal deaths; n = 125
Contributory conditions (pregnancy-related and fetal)		
Fetal distress (O68)	18 (22.2)	20 (16.0)
Fetal abnormality and damage or problems, known or suspected (O35–O36)	13 (16.0)	15 (12.0)
Abnormal pelvic organs, known or suspected (O34)	9 (11.1)	13 (10.4)
Premature rupture of membranes (O42)	<5 (<6.2)	13 (10.4)
Maternal care for known or suspected malpresentation of fetus (O32)	<5 (<6.2)	11 (8.8)
Other disorders of amniotic fluid and membranes[a] (O41)	<5 (<6.2)	<5 (<4.0)
Prolonged pregnancy (O48)	<5 (<6.2)	<5 (<4.0)
Maternal care for other conditions predominantly related to pregnancy[b] (O26)	7 (8.6)	<5 (<4.0)
Contributory conditions (labour and delivery-related)		
Preterm labour and delivery (O60 or gestational age <37 weeks)	20 (24.7)	44 (35.2)
Clinician-initiated preterm delivery[c]	10 (12.3)	30 (24.0)
Perineal lacerations (O70)	18 (22.2)	14 (11.2)
Abnormalities of forces of labour (O62)	12 (14.8)	13 (10.4)
Labour and delivery complicated by umbilical cord complications (O69)	<5 (<6.3)	7 (5.6)
Obstructed labour (O64–O66)	6 (7.4)	5 (4.0)
Other complications of labour or delivery[d] (O75)	23 (28.4)	7 (5.6)
Other characteristics of the delivery hospitalization		
Sepsis, septicemia, or septic shock diagnosis	12 (14.8)	7 (5.6)
Characteristics of the episode of care leading to death		
Sepsis, septicemia, or septic shock diagnosis at death, hospitalization, or episode of care	25 (30.9)	29 (23.2)
Other comorbidities at any hospitalization during pregnancy or in the year prior to death		
Mental health or behavioural disorder	23 (28.4)	48 (38.4)
Substance use	13 (16.0)	32 (25.6)

[a] "Other disorders of amniotic fluid and membranes" (ICD-10-CA code O41) refers to oligohydramnios, infection of amniotic sac and membranes, or other disorders of amniotic fluid and membranes.

[b] "Maternal care for other conditions predominantly related to pregnancy" (ICD-10-CA code O26) refers to excessive or low weight gain in pregnancy, pregnancy care of habitual aborter, retained intrauterine contraceptive device in pregnancy, herpes gestationis, maternal hypotension syndrome, liver disorders, subluxation of symphysis in pregnancy, childbirth, or puerperium or other pregnancy-related conditions.

[c] Based on either a "preterm delivery without spontaneous labour" (ICD-10-CA code O60.3) code, induction (ICD-10-CA code O61 or CCI code 5.AC.30), or cesarean delivery (CCI code 5.MD.60) without any labour (ICD-10-CA code O42, O60.1-O60.2, O62-O69, O71.1, O74-O75.3, O75.7-O75.90).

[d] "Other complications of labour or delivery" (ICD-10-CA code O75) refers to maternal distress during labour and delivery, shock during or after labour and delivery, pyrexia during labour, other complications of obstetric surgery and procedures (including cardiac arrest), delayed delivery after artificial rupture of membranes, delayed delivery after spontaneous or unspecified rupture of membranes, vaginal delivery after previous cesarean delivery, and so on.

Strength and Limitations

The database autopsy method represents a quick and reasonably effective method for identifying the distribution of the underlying causes of maternal death in Canada. However, it has limitations that need to be addressed through a formal, confidential enquiry into maternal deaths. Lack of information on the exact timing of diagnosis, for example, limited our ability to precisely reconstruct the sequence of events. Moreover, we could not assess the extent of mutual aggravation between pregnancy and the diseases identified as indirect causes of maternal deaths. One important weakness of our study was the reliance on the national hospitalization database, which led to the exclusion of maternal deaths among women who delivered or who died outside the hospital. Out-of-hospital deliveries represent only 2% of deliveries in Canada; hence, the missing number of deaths of women of reproductive age within a year of delivery outside of a hospital is likely small.[21] Deaths within a year of spontaneous or medical abortion and out-of-hospital deaths were likely to have been missed in our review.

A strength of our study was the use of information from all hospitalizations during pregnancy and up to 1 year before death, which provided information on previous events that could have been related to death. However, we did not have information on events or conditions that did not lead to hospitalization. A final strength of the study was the high interobserver agreement, which highlights the ease with which a detailed sequential narrative can be used to assign underlying cause of death.

Our review did not include hospitalizations from the province of Québec because data from this province were not included in the Discharge Abstract Database. However, we expect our methodology to be equally applicable to hospitalizations from Québec because the provincial hospitalization database (MED-ECHO) has data fields similar to those in the Discharge Abstract Database.

CONCLUSION

The creation of a sequential narrative of the events leading to maternal death based on all the information available in the Discharge Abstract Database can help to establish the underlying cause of death. The relatively small number of cases of maternal death occurring in Canada annually makes such a "database autopsy" an ideal method for rapidly assessing the underlying causes of maternal death at the national level and for providing information to develop public health initiatives and prevent maternal deaths.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at 10.1016/j.jogc.2020.06.026.

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APPENDIX 1. THREE CLINICAL VIGNETTES BASED ON FICTIONAL DEATH RECORDS (ILLUSTRATING HOW SEQUENTIAL NARRATIVES WERE CREATED AND USED FOR ASSIGNING THE UNDERLYING CAUSE OF MATERNAL DEATH)

Study ID: MM001	
Timing of death	1 day after delivery
Province	[Province]
Age (years) at death:	32
Obstetric Hx:	0 previous preterm delivery 1 previous term delivery 1 previous live birth(s)
Last episode of care	[Admission Date – Discharge Date]
Transfer:	Yes
LoS (days):	3
HOSP 1 (OBS)	[HOSP1code] [Delivery on day 1 at 01h55]
Admission category:	Emergent/Urgent
Entry code:	Patient admitted via the admitting department or directly to the unit
Admission GA (weeks):	34
Delivery GA (weeks):	34
Admission/Pre-admission Comorbidity Diagnosis:	Severe pre-eclampsia (O14.101) Diseases of the circulatory system complicating pregnancy, childbirth and the puerperium (O99.401) Preterm delivery without spontaneous labor (O60.301) Liver disorders in pregnancy, childbirth and the puerperium (O26.601) Endocrine, nutritional and metabolic diseases complicating pregnancy, childbirth and the puerperium (O99.201) Palliative care (Z51.5)
Interventions:	Blood transfusion received: blood product unspecified
Day 1	*Admission time: 01h40* [Unspecified time] In Obstetrics Care Room/Delivery Room/OR: [Delivery at 01h55] Caesarean section delivery, lower segment transverse incision without instrumentation (5.MD.60.AA)[Status: Primary, Indicated, Emergent] Ventilation, respiratory system – positive pressure invasive per orifice approach by endotracheal intubation (1.GZ.31.CA-ND) [extent: continuous] Implantation of internal device via non-tunnelled venous catheter using percutaneous transluminal venous approach. (1.IS.53.GR-LF) [Location: Jugular] Resuscitation, heart NEC by external manual compression with or without concomitant ventilation (1.HZ.30.JN) [Unspecified time] In DI Department: Occlusion, abdominal arteries (percutaneous transluminal approach using synthetic agent) (1.KE.51.GQ.W0)
Day 2	*Died at 12h10*
SCU	Day 1 02h30 to Day 2 12h10 (LoS: 22 hours) in Combined Med/Surg Intensive Care Nursing Unit
Post-admission Comorbidity Diagnosis:	Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium, delivered, with mention of postpartum complication (O99.502) [a] Other post procedural respiratory disorders (J95.88) [a]
Secondary Diagnosis:	Intracerebral haemorrhage in brain stem (I61.3) Intracerebral haemorrhage in hemisphere, subcortical (I61.0) Cardiac arrest with successful resuscitation (I46.0) Other specified diseases of the liver (K76.8) Hyperkalemia (E87.5) Single live birth, pregnancy resulting from both spontaneous ovulation and conception (Z37.000) Pneumonia due to Staphylococcus (J15.2)[a]

(*continued*)

Other (external cause of injury):	Other medical procedures (Y84.8)[a]
Main responsible diagnosis:	HELLP syndrome, Delivered, with or without mention of antepartum condition (O14.201)
Main provider:	Critical care medicine
Other providers:	Obstetrics and Gynaecology
Database autopsy	*Specific diagnosis: HELLP syndrome, Delivered, with or without mention of antepartum condition (O14.201)* *Group: 2 – Hypertensive disorders in pregnancy, childbirth and the puerperium* *Underlying cause of death: HELLP syndrome*
Study ID: MM002	
Timing of death	2h40 after delivery
Province	[Province]
Age (years) at death:	38
Obstetric Hx:	No previous delivery
Last episode of care	[Admission Date – Discharge Date]
Transfer	No
LoS (days):	1
HOSP 1 (OBS + DEATH)	[HOSP1code] [Delivered at 19h47]
Admission category:	Elective
Entry code:	Direct
Admission GA (weeks):	26
Delivery GA (weeks):	26
Admission/Pre-admission Comorbidity Diagnosis:	Morbidly adherent placenta, Delivered, with or without mention of antepartum condition (O43.201) Preterm spontaneous labour with preterm delivery, with or without mention of antepartum condition (O60.101)
Interventions:	Blood transfusion: RBC, plasma
Day 1	*Admitted at 15h25* [Unspecified time] In Obstetrics Case Room/Delivery Room/OR: [Delivered at 19h47] Manually assisted vaginal delivery (vertex) without episiotomy (5.MD.50.AA) [20:35-22:27] in Main Operating Room: External approach for stimulation of heart using electrode converter/defibrillator (1.HZ.09.JA-FS) Compression using intrauterine balloon (5.PC.91.HV) Dilation and evacuation [D&E] (5.PC.91.GD) Dilation and curettage (5.PC.91.GA) Bimanual compression and massage to uterus (5.PC.91.HU) *Died at 22h27*
SCU	No SCU admission
Post-admission Comorbidity Diagnosis:	Other complications of obstetric surgery and procedures (*includes cardiac arrest, cardiac failure, cerebral anoxia*), Delivered, with mention of postpartum complication (O75.402)
Secondary Diagnosis:	Single live birth, pregnancy resulting from both spontaneous ovulation and conception (Z37.000)
Main responsible diagnosis:	Third-stage haemorrhage, Delivered, with mention of postpartum complication (O72.002)
Main provider:	Obstetrics and Gynaecology
Database autopsy	*Specific diagnosis: Morbidly adherent placenta (O43.2)* *Group: 3 - Obstetric Haemorrhage* *Underlying cause of death: Placental disorder*
Study ID: MM003	
Timing of death	210 days after delivery
Province	[Province]
Age (years):	40
Obstetric Hx:	3 previous term deliveries 2 previous live births

(*continued*)

Last obstetrical admission	[Admission Date – Discharge Date]
Transfer:	No
LoS (days):	4
HOSP (OBS)	[HOSPcode] [Delivered on day 2 at 10h43]
Admission category:	Emergent/Urgent
Entry code:	Patient admitted via the admitting department or directly to the unit
Admission GA (weeks):	33
Delivery GA (weeks):	33
Admission/Pre-admission Comorbidity Diagnosis:	Preterm delivery without spontaneous labour, with or without mention of antepartum condition (O60.301) Maternal care for other (suspected) fetal abnormality and damage, delivered with or without mention of antepartum conditions (O35.801)
Interventions:	No blood products received
Day 1:	*Admitted at 13h42*
Day 2:	[9h10-11h12] in Obstetrics care room/Delivery room/OR: Caesarean section delivery, lower segment transverse incision without instrumentation (5.MD.60.AA)
Day 4:	*Discharged at 12h10*
SCU	No SCU admission
Secondary Diagnosis:	Single live birth, pregnancy resulting from both spontaneous ovulation and conception (Z37.000) Supervision of elderly multigravida (Z35.80)
Main responsible diagnosis:	Preterm delivery without spontaneous labour, with or without mention of antepartum condition (O60.301)
Main provider:	Maternal-fetal medicine
Other providers:	Pediatrics
Last episode of care	[Admission Date – Discharge Date]
Transfer:	Yes
LoS (days):	4
HOSP (DEATH)	[HOSPcode]
Admission category:	Emergent/Urgent
Entry code:	Patient admitted via the emergency department of the reporting facility and MUST have utilized ED services (triaged, registered or may have had treatment initiated in the ED)
Admission/Pre-admission Comorbidity Diagnosis:	Aneurysm and dissection of carotid artery (I72.0)
Interventions:	Blood products received: type unspecified
Day 1:	*Admitted at 13h09* [13:16-15:03] in Main Operating room: Drainage, meninges and dura mater of brain by leaving drainage tube [catheter] in situ, open craniotomy/ craniectomy flap approach (1.AA.52.SZ-TS) [Unspecified time] in other unit: Ventilation, respiratory system NEC (positive pressure, invasive per orifice approach by intubation) (1.GZ.31.CA-ND)
Day 4	*Died at 6h49*
SCU	Day 1 15:12 to day 4 6:49 (LoS: 64 hours) in Combined Med/Surg Intensive Care Nursing Unit
Secondary Diagnosis:	Palliative care (Z51.5)
Main responsible diagnosis:	Cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries (I63.5)
Main provider:	Critical care medicine
Other providers:	Anesthesiology, Critical care medicine
Database autopsy	*Specific diagnosis: Aneurysm and dissection of carotid artery (I72.0)* *Group: 7 – Indirect causes* *Underlying cause of death: Diseases of the circulatory system*

APPENDIX 2. ICD-10-CA DIAGNOSTIC CODES USED TO IDENTIFY ADDITIONAL CONTRIBUTORY FACTORS

Factor	ICD-10-CA codes
Mental and behavioural disorders	F^^, O99.3, Z86.5, X6^, X7^, X80-X84, Y87.0, Z91.5
Substance use	F10- F19, T40, T51, R78.0-R78.5, X42, X62

ICD-10-CA: International Statistical Classification of Diseases and Related Health Problems, 10th revision, Canadian version

APPENDIX 3. ADDITIONAL INFORMATION ON EXCLUDED CASES

Of the three cases deemed ineligible, two were deaths of women who had only a "questionable or query diagnosis" for ectopic pregnancy (O00.^), as indicated by a diagnosis prefix "Q", at one hospitalization before death and with no additional codes related to pregnancy or obstetric care within a year of death. The third case was a woman who had a discharge disposition indicating she died during her delivery hospitalization, but there were no diagnostic or intervention codes indicating complications at delivery and she had a subsequent hospital admission with the same identifier (based on the encrypted health card number). Hence, we considered this case to be a coding error.

APPENDIX 4. DIFFERENCES BETWEEN THE TWO REVIEWERS IN IDENTIFYING THE UNDERLYING CAUSE OF DEATH AMONG 25 RANDOMLY SELECTED CASES OF MATERNAL DEATH

Number of cases of disagreement	Cause of disagreement
3	One reviewer identified two potential causes of death (in each case, both causes pertained to group 7), one of which was also the cause identified by the other reviewer in each case.
1	There was disagreement between reviewers, with one reviewer having identified trauma (group 9) as the underlying cause of death and the other identifying drug addiction (group 7) as the underlying cause.