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ORIGINAL ARTICLE

Severe acute maternal morbidity trends in Victoria, 2001–2017

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Background: The incidence of severe acute maternal morbidity (SAMM) is one method of measuring the complexity of maternal health and monitoring maternal outcomes. Monitoring trends may provide a quantitative method for assessing health care at local, regional, or jurisdictional levels and identify issues for further investigation.

Aims: Identify temporal trends for SAMM event rates and maternal outcomes over 17 years in the state of Victoria, Australia.

Materials and Methods: All maternal public health service admissions were extracted from an administrative dataset from July 2000 to June 2017. SAMM-related diagnoses were defined by matching as closely as possible with published definitions. Outcomes included annual SAMM event rates, hospital survival, and hospital length of stay (LOS). Temporal trends were analysed using mixed-effects generalised linear models.

Results: There were 854 777 live births and 1.21 million pregnancy-related hospital admissions which included 34 008 SAMM events in 29 273 records and in 3.42% (95%CI = 3.39–3.46) of births. Most common were severe pre-eclampsia (0.87% of births), severe postpartum haemorrhage (0.59%), and sepsis (0.62%). SAMM-related admissions were associated with longer LOS and higher mortality risk ($P < 0.001$). Maternal mortality ratio remained unchanged at 8.6 fatalities per 100 000 births ($P = 0.65$).

Conclusion: Over 17 years, there was a significant increase in birth rate and SAMM-related events in Victoria. Administrative data may provide a pragmatic approach for monitoring SAMM-related events in maternal health services.

KEYWORDS

acute maternal morbidity, critical care, epidemiology, maternal near miss, mortality

INTRODUCTION

The safety of maternity care has historically been measured using maternal mortality rates.[1] In well-resourced healthcare systems maternal fatalities are rare,[2] restricting the usefulness of mortality metrics to large (national or state) epidemiological reports. Monitoring the frequency of 'maternal near miss' (MNM)[2-4] or 'severe acute maternal morbidity' (SAMM)[5-7] is being progressively adopted as a clinical indicator of maternal healthcare, to monitor patient safety and the quality of maternal care.

Several methods for clinical review of SAMM-related events exist. These include case reports, clinical audit, sentinel event surveillance, and (condition-specific) registries. The national Australasian Maternity Outcomes Surveillance System (AMOSS) limits its work to defined uncommon and life-threatening maternal disease.[8] All Australian states and territories have councils for the purpose of maternal and perinatal outcome review. Most health services undertake internal clinical reviews and audits, but few have published SAMM surveillance results.[9-11]

Peer review within the state of Victoria (Australia) is under the auspice of the Consultative Council on Perinatal and Maternal Morbidity and Mortality (CCOPMM) using data derived from clinical reports and several registries.[12] This includes mandatory reporting of maternal and perinatal deaths, and maternal admissions to an intensive care unit (ICU).[13]

Screening of administrative data[5] for SAMM-related events was validated in New South Wales over ten years ago[14] but is not yet in routine use. In this review, we describe a similar methodology based on screening of administrative data to identify SAMM and associated maternal outcomes. Our objectives were to investigate this methodology and quantify longitudinal (temporal) trends in maternal admission, SAMM-related events, and maternal outcomes across Victoria.

MATERIALS AND METHODS

Victoria is the second most populous state in the Commonwealth of Australia with nearly two million women of childbearing age (15–49 years) and 80 000 births per annum. Fifty-eight public health services provide inpatient maternity healthcare, including three tertiary-referral maternity services.

Data from all hospital medical records inform the Victorian Admitted Episode Dataset (VAED[15]), for the purposes of case-mix funding and epidemiology. The Department of Health and Human Services, Victoria, provides a de-identified extract of the VAED to health services. Each record includes patient demographics, up to 40 diagnoses according to the Australian modification of the International Classification of Diagnoses 10th edition (ICD10-AM[16]), and a maximum of 40 procedure codes according to the Australian Classification of Health Interventions (ACHI[17]).

Data for this report were extracted for the 17 years, from 1 July 2000 to 30 June 2017. Population data for women of childbearing age (age 15–49 years) were extracted from the Australian Bureau of Statistics.[18] Data for non-admitted emergency department visits, home births, and private sector births were not available for analysis.

Data definitions

Birth rate is reported as the number of live births per woman of childbearing age (15–49 years). Births were identified from those hospital records associated with a birth event or a birth-related (ACHI[17]) procedure. Antenatal and postnatal admissions were defined as records associated with a pregnancy-related or a postpartum diagnosis (respectively) and the absence of any code indicating a birth event or procedure.

Several definitions for SAMM and MNM exist.[19] For this study, we combined SAMM and MNM definitions from the World Health Organization (WHO) Maternal Near Miss tool[2,3] and American College of Obstetrics and Gynecologists Consensus Conference[5] (Table 1) to maximise identification of potential categories and cases. ICD-10AM diagnoses and ACHI clinical intervention codes were mapped as closely as possible to these published clinical definitions. See Appendix S1 for more detail. More than one SAMM event was identified in some records. These records were only counted once in the outcome analysis.

Outcomes

Maternal outcomes included the number of live births, the number of hospital admissions with SAMM-related events, the number of maternal ICU admissions, 'maternal mortality ratio' (deaths per 100 000 live births), population mortality (maternal deaths per woman of childbearing age), length of hospital stay (LOS), preterm delivery (gestation ≤32 weeks), and stillbirth (gestation >20 weeks).

Statistical analysis

Grouped data are reported as mean (±standard error), median (interquartile range), or 95% confidence intervals (95% CI), where appropriate. Annualised temporal trends and risk-adjustment, reported as odds ratio (OR) and incident rate ratio (IRR) for binary or continuous variables (respectively), were obtained by fitting generalised linear regression models on admissions coded with SAMM event(s) with patient demographics (age, transfer from other health service, emergency admission), pre-existing chronic (cardiac, respiratory, renal, hepatic or neurological) disease and hospital site as a random intercept. Year of separation (Year) was confirmed as a continuous variable for temporal trends by first fitting it as a categorical variable.

The Eastern Health Human Research Ethics Committee (LR73/2017) approved this observational study and the need for patient consent was waived. All records were de-identified.

TABLE 1 Severe acute maternal morbidity categories and definitions

SAMM category	Definition
Severe PPH	PPH plus any of following: (a) surgical intervention, balloon tamponade, B-lynch suture, hysterectomy; (b) radiological intervention, embolisation; (c) blood transfusion plus coagulopathy, thrombocytopaenia, or coagulation factor transfusion
Severe pre-eclampsia	Severe pre-eclampsia, HELLP syndrome, eclampsia; or moderate pre-eclampsia plus admission to intensive care unit
Sepsis	Infection plus signs or diagnosis of organ dysfunction or acidosis; or septic shock
Anaesthesia-related complications	Post-neuraxial block headache, local anaesthesia toxicity, anaphylaxis, aspiration pneumonitis, circulatory shock
Abortion-related complications	Excessive haemorrhage, infection, or embolic complications
Uterine rupture	Uterine rupture in association with delivery
Acute kidney injury	Acute kidney injury or acute haemofiltration/dialysis
Emergency hysterectomy	Hysterectomy in association with delivery, excluding diagnosis of malignancy
Circulatory shock	Cardiogenic or hypovolaemic shock, cardiac arrest
Laparotomy	Laparotomy in association with delivery, excluding caesarean delivery or diagnosis of malignancy
Embolic disease	Pregnancy-associated pulmonary emboli (air, amniotic fluid, fat, or thrombus)

HELLP, haemolysis, elevated liver enzymes, low platelet count; PPH, postpartum haemorrhage; SAMM, severe acute maternal morbidity.

Analysis was performed using Stata V14.2 (2016, StataCorp, College Station, TX, USA).

RESULTS

The number of women of childbearing age (15–49 years) in Victoria increased by 29.1% to 1.98 million by 30 June 2017. Over 17 years, there were 854 777 births and 1.21 million pregnancy-related admissions, an average of 1.42 ± 0.08 admissions per birth (Fig. 1). The annual birth rate was 29.0 (95% CI, 28.8–29.3) per 1000 women of childbearing age, and increased by 0.8% per annum ($P < 0.001$).

SAMM events

There were 29 273 hospital records coded with 34 008 SAMM-related events, at an average of 1.16 (95% CI, 1.15–1.17) separate events per record, in 3.42% (95% CI, 3.39–3.46) of births. The rate of SAMM events is provided in Figure 1. Most episodes of SAMM occurred during a birth-related admission (69%) rather than during antenatal (16%) or postnatal (15%) admission.

Over 17 years, the incidence of SAMM-related events increased from 2.96% (95% CI, 2.80–3.12) in 2001 to 4.68% (95% CI, 4.50–4.86; $P < 0.001$) of births in 2017. Four SAMM diagnoses

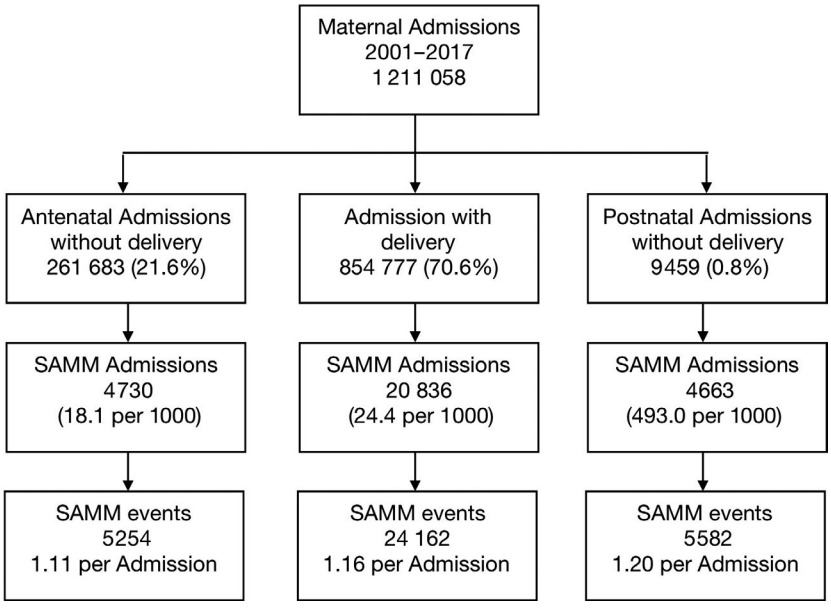

FIGURE 1 CONSORT (Consolidated Standards of Reporting Trials) diagram for study population.

(postpartum haemorrhage (PPH), hysterectomy, pre-eclampsia, and anaesthesia complications) with different temporal trend patterns are presented in Figure 2. The proportion of maternal admissions coded with chronic disease or acute organ dysfunction also increased over time (see Fig. 3, and Appendix S1 for definitions.)

SAMM-related events were more often associated with admission to a tertiary maternity service, with admission to ICU, and with surgical or premature delivery ($P < 0.01$). Thus tertiary-referral hospitals reported higher SAMM rates (5.75%; 95% CI, 5.59–5.91) than other hospitals (3.16%, 95% CI, 3.12–3.320; $P = 0.01$). The rate of SAMM was higher in Indigenous (3.93%; 95% CI, 3.48–4.42%) than non-Indigenous (3.42%; 95% CI, 3.38–3.46%; $P = 0.02$) mothers.

Frequency, rate, and risk-adjusted temporal trend for each SAMM category are summarised in Table 2. Further information regarding risk adjustment is provided in Appendix S2. The most frequent SAMM events were severe pre-eclampsia/eclampsia (25.0% of SAMM-related admissions), sepsis (18.0%) severe PPH (17.4%), anaesthesia (8.4%) or abortion-related (11.6%) complications, and circulatory shock (3.8%). Multiple SAMM-related events were present in 3864 records (13.2% of SAMM-related admissions, and 0.32% of births).

Severe PPH and pre-eclampsia

There were a total of 120 078 admissions (95% CI, 14.0–14.1% of births) coded with PPH, with only 5084 (95% CI, 0.58–0.61% of births) fulfilling our criteria for severe PPH. Similarly, there were 62 014 admissions (95% CI, 7.2–7.3% of births) coded with pre-eclampsia, with only 7440 (95% CI, 0.85–0.89% of births) fulfilling the criteria for severe pre-eclampsia/eclampsia.

Transfer

There were 28 133 admissions and 9485 (1.11%) births preceded by an inter-hospital transfer for ongoing acute care: 2845 (10.1%; 95% CI, 9.7–10.5%) maternal transfers were coded with a SAMM-related event and this was significantly higher than the corresponding rate for direct admissions (2.2%; 95% CI, 2.2–2.3%, $P < 0.001$).

Caesarean delivery

The proportion of surgical deliveries increased from 24.4% (95% CI, 24.0–25.0) in 2000 to 35.2% (95% CI, 34.7–35.7) in 2017 but the proportion with SAMM events in this cohort (4.46%; 95% CI, 4.38–4.55) did not change ($P = 0.98$).

Maternal outcomes

SAMM-related events were present in 1967 (57.1%) of 3445 maternal ICU admissions, and in 801 (73.6%) of those receiving invasive respiratory support (mechanical ventilation) in ICU.

There were 71 in-hospital maternal deaths reported over 17 years, giving a 'maternal mortality ratio' (MMR) of 8.6 (95% CI 2.7–21.2) deaths in 100 000 births. Most ($n = 68$: 96%) occurred in health services with on-site (maternal) intensive care services.

Admissions to tertiary maternity hospitals were associated with a significantly higher MMR (49.6; 95% CI, 36.1–66.6) than non-tertiary hospitals (3.52; 95% CI, 2.32–5.13; $P = 0.01$). The MMR

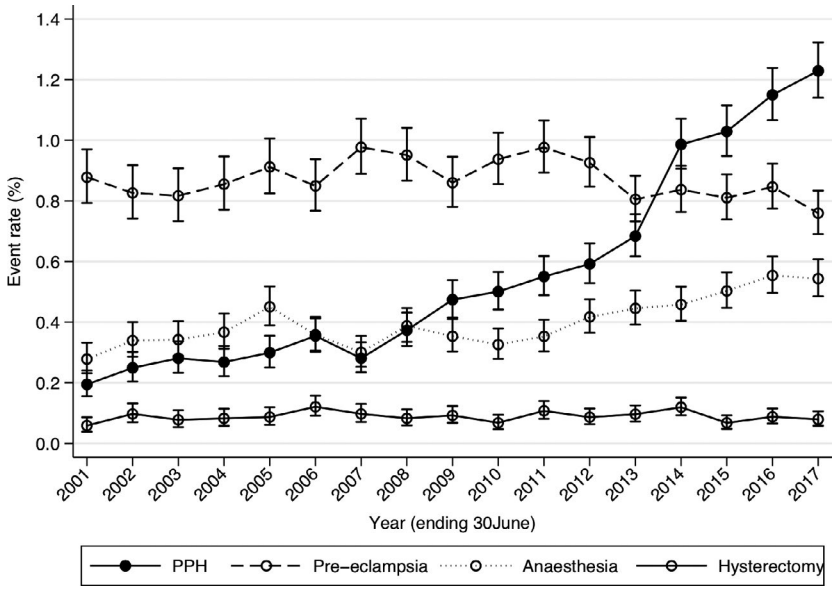

FIGURE 2 Temporal trend (95% CI) patterns for selected severe acute maternal morbidity (SAMM) events: PPH = severe postpartum; haemorrhage; Pre-eclampsia = severe pre-eclampsia/eclampsia; Anaesthesia = maternal complications during anaesthesia; Hysterectomy = emergency hysterectomy.

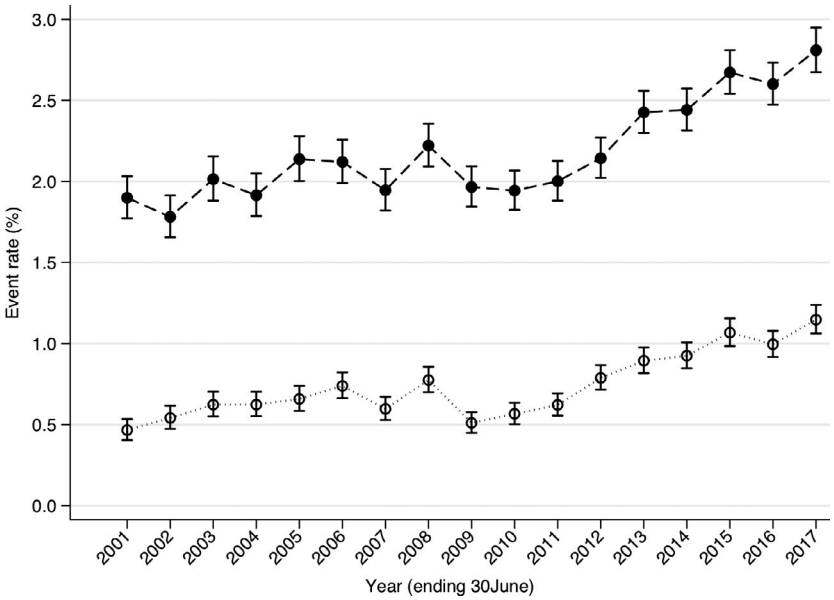

FIGURE 3 Temporal trend (95% CI) for proportion of births associated with maternal acute organ dysfunction on admission (closed circle, dashed line) or chronic diseases (open circle, dotted line). *P*-value < 0.001.

for admissions with SAMM-related events was significantly higher (290 per 100 000 births) than in those without (1.32 per 100 000 births; *P* < 0.0001).

The admission diagnoses of in-hospital maternal death included PPH (*n* = 16; 26.67%), septic shock (*n* = 13; 21.67%), cardiac failure (*n* = 5; 8.33%), pregnancy-related hypertension (*n* = 6; 10%), and embolic disease (*n* = 6; 10%).

There were 6979 stillbirths (0.80%) and 20 898 (2.44%) premature (<33 weeks gestation) deliveries. The annual age-adjusted MMR (*P* = 0.65), stillbirth rate (*P* = 0.07), and premature delivery rate (*P* = 0.11) remained static.

SAMM-related admissions were associated with a longer length of hospital stay (4 days (interquartile range (IQR) = 2–6) vs 2 days (IQR = 1–4); *P* < 0.001). There was a small but significant temporal decline in hospital LOS independent of the presence of SAMM (IRR = 0.99 per year, *P* < 0.001).

DISCUSSION

We adopted a technique for identifying SAMM events using administrative data based on ICD10AM[16] and ACHI,[17] and applied this method in a dataset spanning 17 years in Victoria. The baseline SAMM rate (3%) has slowly increased to an average rate of one in 20 (4.68%) of births.

Our estimate of SAMM incidence falls within the range of estimates reported in other developed countries (3.6–18.4%).[1] The observed rates for common SAMM categories such as severe PPH,[20] severe pre-eclampsia, and sepsis[21] were also similar to published rates.[1,4,6,14] SAMM events were found to be associated with a doubling of hospital stay and an increased mortality risk.

There are several methods for capturing and reporting SAMM-related events.[8-14] We expanded and demonstrated one method

TABLE 2 Severe acute maternal morbidity (SAMM) frequency and temporal trend

SAMM category	*n* (% total)	Rate (95% CI)	OR	*P*-value
All	30,229	3.54 (3.50–3.58)	1.02–1.05	<0.001
Severe pre-eclampsia	7440 (24.6)	0.87 (0.85–0.89)	0.99–1.02	0.64
Sepsis	5269 (17.4)	0.62 (0.60–0.63)	0.98–1.02	0.89
Severe PPH	5084 (16.8)	0.59 (0.58–0.61)	1.14–1.18	<0.001
Anaesthesia	3470 (11.5)	0.41 (0.39–0.42)	1.02–1.05	0.001
Abortion-related	3400 (11.2)	0.40 (0.38–0.41)	0.98–1.03	0.95
Circulatory shock	1127 (3.7)	0.13 (0.12–0.14)	1.03–1.08	<0.001
Uterine rupture	1091 (3.6)	0.13 (0.12–0.14)	0.94–1.01	0.07
Embolic disease	894 (3.0)	0.10 (0.10–0.11)	0.96–1.02	0.43
Acute kidney injury	800 (2.6)	0.09 (0.09–0.10)	1.11–1.15	<0.001
Hysterectomy	760 (2.5)	0.09 (0.08–0.10)	1.00–1.05	0.02

OR, odds ratio; PPH, postpartum haemorrhage.

based on ICD10AM and ACHI codes[17] that affords a number of advantages.

Monitoring of SAMM provides an index of patient complexity and, after risk-adjustment, may provide an indicator of maternal safety and healthcare. Some categories of SAMM are potentially preventable.[21,22] Benchmarking of complexity and outcome is possible with surveillance at a jurisdictional level.

Administrative data are comprehensive and based on an international (ICD10AM) coding standard that all states in Australia and New Zealand utilise. These datasets can be linked to perinatal outcome registries.[8,13,14]

Administrative data also have several inherent limitations. The reliability of administrative data is limited by the quality of medical documentation and clinical coding. However, the Victorian dataset (VAED) does undergo regular data quality audits[23] and a similar methodology based on administrative data has been validated in New South Wales.[14]

Exact matching of ICD10AM codes with every SAMM category is not possible. For example, codes for PPH and blood transfusion do not quantify the volume of blood lost or delivered.[20] Thus we excluded from our definition of severe PHH those records where blood transfusion was the sole intervention (Table 1) and this may have led to an underestimate of the true rate.

Each episode coded with SAMM was assumed to be unique. We were unable to exclude readmission of the same patient except in 5% of SAMM episodes following acute inter-hospital transfer. This may have inflated the frequency of SAMM events (numerator). Conversely, the number of births (denominator) may be an underestimate of total women at risk and deflated the true SAMM rate. A more applicable denominator for abortion-related complications may be the total number of pregnancies, rather than live births.

Our dataset did not include the private sector which accounts for approximately 20% of all births and 5% of SAMM-related ICU admissions in Victoria.[15] Total births in the private sector have declined in recent years and maternal transfer to the public health system (0.01%) remains low.[9,15]

Any system derived from administrative data should be restricted to screening and not diagnostic purposes. It provides direction for further enquiry and should not be employed as an arbiter of the quality of care. It does not afford the same depth of clinical insight, and should not replace detailed clinical review of individual case records.[9-12] For example, the temporal increase in some SAMM event rates, notably severe PPH and pre-eclampsia, should not be interpreted as indicating a decline in quality of maternal care. It may simply reflect improvements in diagnosis, documentation, and coding.

Despite these limitations, our methodology provides one pragmatic option for the assessment of SAMM. Several aspects warrant further investigation. These include validation of the mapping algorithm, linkage to perinatal outcomes, risk-adjustment and benchmarking, prediction and prevention, and refinement of SAMM categories.

For example, most SAMM and MNM systems classify 'maternal ICU admission' as an inclusion criterion.[1-6] This appears reasonable given our findings that over one-half (57%) of maternal ICU admissions were associated with SAMM events, and two-thirds (66%) of maternal deaths followed an ICU admission. However, ICU admission as the sole criterion for SAMM is insufficient since 90% of SAMM events were managed without ICU admission, and over one-half (53%) of maternal healthcare services in Victoria do not have access to on-site (or co-located) adult intensive care services.

In conclusion, administrative datasets reveal an increasing incidence of SAMM-related hospital admissions over a 17-year period. While patients admitted with SAMM had longer LOS and higher mortality risk, these did not change over time. Screening of administrative data offers a pragmatic tool for continuous monitoring of maternal complexity and the prevalence of maternal morbidity, and affords insight into maternal safety and healthcare delivery.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Severe acute maternal morbidity (SAMM) Australian modification of the International Classification of Diagnoses 10th edition (ICD10AM) coding methodology.

Appendix S2. Severe acute maternal morbidity (SAMM) explanatory model.