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Maternal trauma due to motor vehicle crashes and pregnancy outcomes: a systematic review and meta-analysis

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ABSTRACT

Objectives To systematically review and quantify the effect of motor vehicle crashes (MVCs) in pregnancy on maternal and offspring outcomes.

Design Systematic review and meta-analysis of observational data searched from inception until 1 July 2018. Searching was from June to August 2018 in Medline, Embase, Web of Science, Scopus, Latin-American and Caribbean System on Health Sciences Information, Scientific Electronic Library Online, TRANSPORT, International Road Research Documentation, European Conference of Ministers of Transportation Databases, Cochrane Database of Systematic Reviews and Cochrane Central Register.

Participants Studies were selected if they focused on the effects of exposure MVC during pregnancy versus non-exposure, with follow-up to verify outcomes in various settings, including secondary care, collision and emergency, and inpatient care.

Data synthesis For incidence data, we calculated a pooled estimate per 1000 women. For comparison of outcomes between women involved and those not involved in MVC, we calculated ORs with 95% CIs. Where possible, we statistically pooled the data using the random-effects model. The quality of studies used in the comparative analysis was assessed with Newcastle–Ottawa Scale.

Results We included 19 studies (3 222 066 women) of which the majority was carried out in high-income countries (18/19). In population-level studies of women involved in MVC, maternal death occurred in 3.6 per 1000 (95% CI 0.25–10.42; 3 studies, 12 000 women; Tau=1.77), and fetal death or stillbirth in 6.6 per 1000 (95% CI 3.81–10.12; 8 studies, 47 992 women; I^2=92.6%). Pooled incidence of complications per 1000 women involved in MVC was labour induction (276.43), preterm delivery (191.90) and caesarean section (166.65). Compared with women not involved in MVC, those involved had increased odds of placental abruption (OR 1.43, 95% CI 1.27–1.63; 3 studies, 1 500 825 women) and maternal death (OR 202.27; 95% CI 110.60–369.95; 1 study, 1 094 559 women).

Conclusion Pregnant women involved in MVC were at higher risk of maternal death and complications than those not involved.

PROSPERO registration number CRD42018100788.

Strengths and limitations of this study

- This is the first systematic review examining the link between involvement in motor vehicle crashes (MVCs), mortality and adverse outcomes that includes evaluation of study quality assessment.
- This is the second systematic review looking at outcomes following MVC in pregnancy.
- We conducted our review using a prospectively registered protocol and reported it in accordance with the international standards.
- Outcomes variables correspond to any trimester, not to specific trimesters.
- Outcomes according to seat belt use are scarce, since only two studies use population-level data.

INTRODUCTION

Up to half of all women in developed countries drive motor vehicles[1] and the consequences of road traffic-related injuries involving pregnant women can be severe.[2] Indeed, motor vehicle crashes (MVCs) are the most common cause of non-obstetric trauma associated with fetal deaths (2.3 per 100 000 live births).[3] The risk of adverse outcomes resulting from an MVC increases in the second trimester of pregnancy if the pregnant women were the driver[4] ; however, this does not appear to be the case for pregnant passengers or pedestrians.[5] A maternal mortality rate of 3.5 women per 100 000 is reported following MVCs in pregnant women.[6] Mechanisms of injury recorded within the pregnant population of the UK national trauma registry, the Trauma Audit and Research Network, saw an increased rate of vehicular collision in pregnant women when compared with the non-pregnant cohort.[7] In 2001–2008, 2.9% of pregnant women in North Carolina were drivers in one or more crashes.[8] In the USA, data from the National Automotive Sampling System/Crashworthiness Data System reflect that when vehicles with pregnant women are involved in collision, 50% of those women will sustain an injury.[9] There are few safety guidelines on travelling by car during pregnancy.[10–12] The focus of these tends to be on questions around the use of seat belts and the activation of airbags in the car.[12]

There is a reported association between MVC and maternal mortality.[13] Moreover, further associations such as the trigger for immediate delivery or being more likely to die are reported with severe blunt injury (Injury Severity Score (ISS) of 9 or above, or systolic blood pressure <90 mm Hg on arrival).[14] Involvement in MVC is also associated with perinatal mortality,[15] injuries to the abdominal region,[16] placental abruption secondary to increased intra-abdominal pressure,[17] preterm birth and caesarean section.[6] However, more data are required in relation to areas such as fetal outcomes and higher risk pregnancies, particularly regarding sociodemographic characteristics of the mother, specific trimester of pregnancy when exposed to trauma, socioeconomic country conditions, severity and type of trauma, and collision characteristics such as speed. A systematic review on trauma in pregnancy (including five studies reporting complications of involvement in MVC, and fourteen other studies on other forms of trauma) showed that MVC and domestic violence were the most common causes of traumatic injury during pregnancy.[4] No quality assessment of the included studies was reported in this review. Previous non-systematic reviews have published strategies used to monitor women and fetuses after a crash.[18–21] However, to our knowledge there is no systematic review or meta-analysis focused on the maternal and fetal outcomes after MVC in pregnancy.

Review objectives

As the clinical impact on the mother and fetus after MVC has not been well documented, we conducted a systematic review of the effect on maternal and fetal outcomes of MVC in pregnant women, compared with those not involved in a collision.

METHODS

We conducted a systematic review and reported it according to recommended standards.[22]

Literature search

Searching was from June to August 2018. The following databases were used to identify relevant literature: Medline, Embase, Web of Science, Scopus, Latin-American and Caribbean System on Health Sciences Information, Science Citation Index, Scientific Electronic Library Online, TRANSPORT, International Road Research Documentation, European Conference of Ministers of Transportation Databases, Cochrane Database of Systematic Reviews and Cochrane Central Register of Controlled Trials. We also sought to identify unpublished research or research reported in the grey literature by searching a range of relevant databases, including the Inside Conferences, Systems for Information on Grey Literature and Dissertation Abstracts. Furthermore, the searches of the medical database were supplemented with the internet search using a general search engine (eg, Google, www.google.co.uk/) and safetylit.org. Language and date restrictions were not applied to electronic searches. Relevant studies were identified using a combination of, but not limited to, the medical subject headings and keywords for “motor vehicle collision” (OR road traffic collision OR crash OR collision) and “pregnancy” (OR pregnant women OR gravid women OR childbearing women OR maternal).

Review inclusion criteria

Papers were selected if they studied the effects of exposure to trauma due to involvement in an MVC during pregnancy versus non-exposure, with follow-up to verify outcomes in various settings including secondary care, collision and emergency, and inpatient care. Observational studies (cohort studies, case–control design, non-intervention arms of randomised controlled trials) were included. Case series and case reports were excluded. Online supplemental appendix 1 shows the search strategy for Medline (via Ovid) and online supplemental appendix 2 the excluded studies with reasons.

Data extraction and study quality assessment

A double screening of papers was carried out. Two reviewers (CA-P and JR) independently extracted the relevant data from each full-text article and data were recorded using a standardised data extraction form. A data extraction form was piloted for each study design and amended as required. Discrepancies were resolved by consensus or by a discussion with a third senior author (ER). We extracted data on (a) severe adverse maternal outcomes such as maternal death, miscarriage and preterm birth (<37/40 and <34/40); (b) severe adverse fetal outcomes such as intrauterine death/stillbirth and neonatal death. Secondary outcomes were: (a) individual components of maternal outcomes such as preterm labour, mode of delivery (vaginal delivery vs caesarean section), premature rupture of membranes (PROM), preterm PROM, placental abruption, chorioamnionitis/sepsis and maternal admission to an intensive care unit (ICU) or high dependency unit; (b) individual components of fetal outcomes: respiratory distress syndrome, neonatal ICU admission, low birth weight and small for gestational age.

We also extracted data on (1) adverse outcomes in pregnant women involved in MVC and their offspring in subgroups according to maternal characteristics (low, high and any risk), trimester of exposure, country (low and middle income, high income), type of trauma (penetrating, blunt, burns), severity of trauma (mild, moderate, severe), seat belt use (yes, no), study quality (low, high); (2) risk factors for pregnancy complications following MVC such as maternal characteristics (age, parity, high risk pregnancy, gestational age), type of trauma, type of motor vehicle, type of collision, collision characteristic (stationary, high or moderate speed) and seat belt use.

The quality assessment of studies was independently evaluated by two reviewers (JR and CA-P) using the Newcastle–Ottawa Scale.[23] This scale includes 8 items, 4 items about selection criteria of cases or cohorts in case–control or cohort designs, respectively; 2 items about comparability between groups (in both designs); and 3 items about exposure criteria in case–control designs and about outcomes in cohort designs. Any of those studies could be awarded a maximum of one star for each numbered item within the selection and exposure categories. A maximum of two stars could be given for comparability. For the incidence analysis, we considered six aspects[24]: (1) representativeness of cohort; (2) design; (3) method of sampling; (4) adequacy of follow-up; (5) if the outcomes were adequately ascertained and (6) if measurement or misclassification bias was minimised. Studies without these features or with unclear reporting were classified to have a high risk of bias.

Patient and public involvement

No patient involved.

Data synthesis

We undertook random-effects meta-analysis to determine the ORs with 95% CIs for maternal and offspring complications from MVC. We estimated heterogeneity between the included studies with X^2 test of Q (I^2) excepting when not enough studies were in the meta-analysis,[2 3] and we pooled the rates of maternal/fetal complications and reported with 95% CI. For each primary outcome, a meta-analysis was conducted for studies sufficiently homogeneous in terms of the characteristics of participants and exposure. The subgroup analysis was applied in: (a) trimester of pregnancy during which the trauma occurred; (b) maternal risk status (low, high, any risk); (c) type of trauma; (d) severity of trauma (using the ISS to categorise the severity of trauma sustained following MVC)[25]; (e) setting (low/middle-income, high-income country); (f) year of study publication: (before or after the introduction of mandatory seat belt legislature in the country of study); and (g) study quality according to the Newcastle and Ottawa Scale.[23]

RESULTS

Study selection

Out of 1739 retrieved references, 19 studies met the eligibility criteria (figure 1). Five of these reported data allow us to compare pregnancy complications between pregnant women involved in MVC and those not involved in MVC.[6 8 26–28] The totality of the studies (n=19) contributed to the analysis of the incidence of pregnancy complications among women involved in MVC.[6 17 26–40]

Characteristics of included studies

The characteristics of included studies are in table 1. Included studies were published between 1993 and 2016. Most of them were carried out in developed, high-income countries such as the USA (14/18),[8 26 28–30 32–39] Sweden (1/19),[27] Kuwait (1/19)[17] and Israel (1/19).[40] The number of included pregnant women varies, ranging from 39 to 1 094 559. The data were sourced from hospital records/trauma registries (7/19)[17 30 31 34 37 38 40] or from population-level databases (12/19).[2 6 8 26–29 32 33 35 36 39] The majority of studies collected information on outcomes of pregnant women involved in MVC during any trimester of pregnancy. Eight out of 19 studies reported information about the use of safety devices such as seat belts and/or airbags.[26 29 32 34 36–38] Also in eight studies, the authors assessed the severity of MVC injuries with five of these using a validated tool[28 30 34 37 40]—most of them reporting ISS[28 30 34 40] and one the Revised Trauma Scale.[37]

Quality assessment

Sixty per cent of studies had a low risk of bias with regards to the adequacy of representativeness and random sample selection (12/19). None of the studies was prospective. The categories of follow-up of more than 80% of participants, outcome ascertainment and misclassification bias showed low risk (figure 2). The five papers included for comparison of complication rates between pregnant women exposed to MVC and those who were not exposed (assessed using the Newcastle–Ottawa Scale) showed generally high quality, with four papers scoring 9/9 (6, 26, 28, 29). The remaining paper scored 8/9, losing 1 point for the comparability as it did not control for any secondary factors.[27]

Incidence of complications among pregnant women involved in MVCs

The assessment of adverse outcome incidence among women involved in MVC (using population-level data) demonstrated incidence estimations of 276.43 per 1000 for induction of labour (95% CI 262.54–290.54), 191.90 per 1000 for preterm delivery (95% CI 45.98–405.74) and 166.65 per 1000 for caesarean section (95% CI 47.34–339.00). The estimated incidence rates for other complications included 42.33 per 1000 for PROM, 17.08 per 1000 requiring admission to hospital, 16.14 per 1000 for placental abruption and 15.19 per 1000 for neonatal respiratory distress. A pooled incidence of maternal death was 3.60 per 1000 women (95% CI 0.25–10.42, 3 studies, 12 000 women, Tau=1.77). The pooled incidence of perinatal death (fetal death or stillbirth) per 1000 women was 6.60, (95% CI 3.81–10.12; 8 studies, 47 992 women; I^2=92.6%) (table 2). The representation of the maternal and offspring outcomes according to trauma severity are in appendices (online supplemental appendices 3 and 4). Using data from single hospital centres, the random pooled estimation for the incidence of admission to hospital was 117.92 per 1000 women (95% CI 109.82–126.40)[17 37]; for maternal death was 135.05 per 1000 women (95% CI 131.37–138.80) and for fetal death was 5.73 per 1000 women (95% CI 3.05–9.77) (online supplemental appendices 5 and 6).

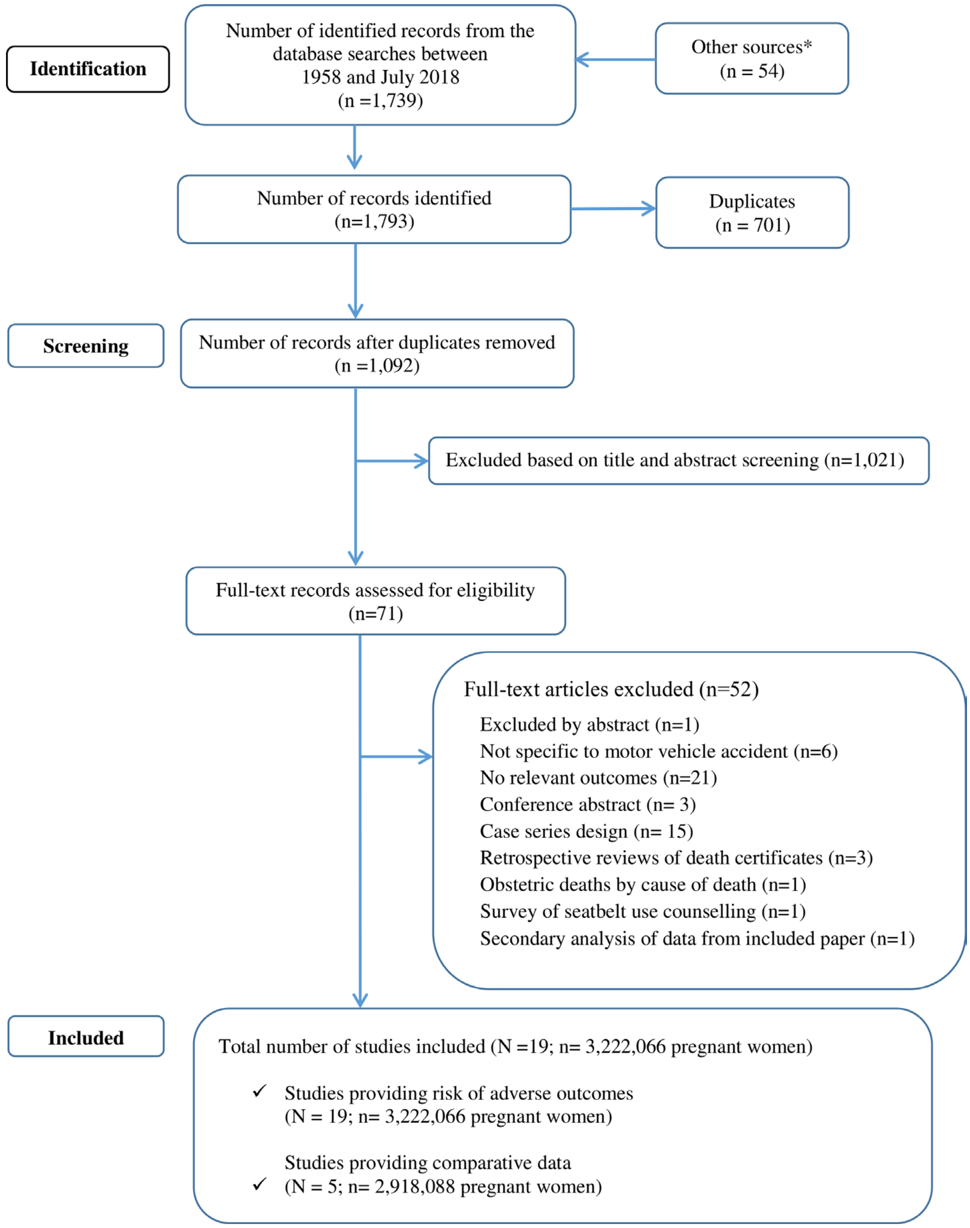

Figure 1 The study selection process in the systematic review of outcomes on pregnant women involved in motor vehicle crashes.*references of relevant non-systematic reviews and Google Scholar.

Pregnancy complications in women involved versus not involved in MVCs

We observed a statistically significant link between involvement in MVC and maternal death (OR 202.3, 95% CI 110.60–370.00; single study)[27] (data not shown in table or graphic). Figure 3 shows pooled results from population-level data, demonstrating a positive association between MVC and placental abruption (OR 1.43 95% CI 1.27–1.63). Two studies contributed data used in sensitivity analyses stratifying by seat belt use, where the pooled estimation[26] of fetal death decreased with seat belt devices, but the association was not statistically significant (OR 0.66 95% CI 0.36–1.19) (online supplemental figure 1). The review manager forest plot displays a positive but not statistically significant association between fetal death and MVC without seat belt use (OR 5.78 95% CI 0.17–201.12, Tau^2=6.51) (online supplemental figure 2).

DISCUSSION

Statement of principal findings

This review estimated that for women involved in MVC, maternal death occurrence was 3.6 per 1000 and perinatal death 6.6 per 1000 women. Compared with women not involved in MVC, those involved had an increased odds of placental abruption, antepartum haemorrhage and maternal death. The pooled incidence of complications per 1000 women involved in MVC was, from the higher incidence to the lower, induction of labour,

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Table 1 Characteristics of included studies

Study ID author, year, country	Design	Sample size	Time period	Inclusion criteria	Data source	Trimester	Seat belt use (with data)	Assessment of trauma severity (with data)	Method of assessing trauma severity	Maternal outcomes	Offspring outcomes
Population-level data											
Azar *et al*,[2] 2015, USA	Population-based matched retrospective cohort (incidence only)	5936	2003–2011	Admitted to hospital following MVC while pregnant	Population-based cohort	Any	No	No	N/A	Maternal death	–
Hyde *et al*,[26] 2003, USA	Retrospective cohort (incidence and comparison)	322 704	1992–1999	Pregnant drivers involved in MVC	Linked databases (police registry and birth/death certificates)	Any	Yes	Yes	Study-specific definition‡	–	Fetal death
Kvarnstrand *et al*,[27] 2008, Sweden	Retrospective cohort (incidence and comparison)	1 094 559	1991–2001	Maternal inclusion on the accident register >28 GW	Linked databases (police registry and birth/death certificates)	2nd	No	Yes	Study-specific definition§	Maternal death	Fetal/neonatal death
Kuo *et al*,[33] 2007, USA	Retrospective chart/database review (incidence only)	16982 injuries 4479 (in MVC)	2002	Pregnant women hospitalised with injury (only MVC used)	Sample from population level cohort (National Inpatient Sample)	Any	No	No	N/A	Delivery, hospitalisation	–
Schiff and Holt,[28] 2005, USA	Retrospective cohort (incidence and comparison)	17 899	1989–2001	Hospitalised for MVC and with a singleton live birth or fetal death	Linked databases (hospital discharge data and birth/death certificates)	Any	No	Yes	ISS	Preterm birth, PROM, C-section, placental abruption	Stillbirth, LBW, SGA, fetal distress, RDS, meconium
Schiff *et al*,[36] 2010, USA	Retrospective cohort (incidence only)	3348	2002–2005	Non-rollover MVC among pregnant front seat occupants	Linked databases (hospital discharge data and birth/death certificates)	Any	Yes (airbag); no (seat belt)	No	N/A	Preterm birth, placental abruption, labour induction, C-section	Stillbirth, LBW, SGA, RDS, fetal distress, meconium
Vivian-Taylor *et al*,[6] 2012, Australia	Retrospective cohort (incidence and comparison)	604 380	2000–2007	Women who gave birth exposed and not exposed to MVC	Linked databases (hospital discharge data and birth/death certificates)	2nd	No	Yes	Study-specific definition¶	Admission, placental abruption, APH, PPH, preterm birth, C-section	Perinatal death (>20th GW), neonatal transfer

Continued

Table 1 Continued

Study ID author, year, country	Design	Sample size	Time period	Inclusion criteria	Data source	Trimester	Seat belt use (with data)	Assessment of trauma severity (with data)	Method of assessing trauma severity	Maternal outcomes	Offspring outcomes
Vladutiu *et al*,[8] 2013, USA	Retrospective cohort (incidence and comparison)	878 546	2001–2008	Pregnant women 16–46 years, >20 GW, delivering a live/stillbirth singleton infant	Linked databases (police registry and birth/death certificates)	2nd	Yes (seat belt); yes (airbag)	No	N/A	Placental abruption, PROM, preterm birth	Stillbirth
Weiss and Strotmeyer,[32] 2002, USA	Crash database pregnant versus non-pregnant (NASS/CDS) (incidence only)	32 810	1995–1999	Pregnant and non-pregnant women 15–39 years	Sample from population-level database of traffic accidents	Any	Yes	No	N/A	Maternal death	–
Weiss *et al*,[35] 2008, USA	Retrospective cohort (incidence only)	1816	1999–2002	Injury-related emergency department visits by pregnant women (only MVC used)	Linked databases (hospital discharge data and birth/death certificates)	Any	No	No	N/A	Hospital admission	–
Whitehead,[39] 2013,* USA	PRAMS survey database (incidence only)	235 329	2000–2005	Survey of women who recently delivered a live-born infant	Population-based cohort (PRAMS)	Any	No	No	N/A	Preterm birth, UTI, PROM	–
Wolf *et al*,[29] 1993, USA	Population-based retrospective cohort (incidence only)	2582	1980–1988	Pregnant women drivers involved in MVC >20GW	Linked databases (police registry and birth/death certificates)	2nd and 3rd	Yes	No	N/A	Preterm birth, placental abruption, C-section	Stillbirth, LBW, RDS
Single hospital records/trauma registry											
Aboutanos,[34] 2007, USA	Retrospective chart/database review (incidence only)	148	2001–2005		Single hospital records from trauma centre	Any	Yes (only in miscarriage)	Yes	ISS	Maternal death, miscarriage	Fetal death hydrops fetalis
Baerga-Varela *et al*,[30] 2000, USA	Retrospective chart/database review (incidence only)	39	1986–1996		Single hospital records	Any	No	Yes	ISS	Maternal death, miscarriage	Stillbirth
Brookfield *et al*,[37] 2013, USA	Retrospective chart/database review (incidence only)	256	1990–2007		Single hospital records from trauma centre	Any	Yes	Yes	ISS and RTS	Maternal death, admission to hospital	–

Continued

Table 1 Continued

Study ID author, year, country	Design	Sample size	Time period	Inclusion criteria	Data source	Trimester	Seat belt use (with data)	Assessment of trauma severity (with data)	Method of assessing trauma severity	Maternal outcomes	Offspring outcomes
Chibber *et al*,[17] 2015, Kuwait	Retrospective chart/database review (incidence only)	728		2009–2012	Single hospital records	2nd	No	No	N/A	Maternal death, placental abruption, preterm birth, uterine rupture, C-Section, admission	Fetal death, fetal distress
Luley *et al*,[38] 2013, USA	Retrospective chart/database review (incidence only)	126		1994–2010	Single hospital trauma database	2nd and 3rd	Yes	No	N/A	Maternal death, placental abruption, C-section	Stillbirth
Miller *et al*,[40] 2016, Israel	Retrospective cohort (incidence only)	3794		2006–2013	National trauma registry	Any	No	No	ISS	Maternal death, miscarriage, placental abruption, C-section	Stillbirth
Orji *et al*,[31] 2002, Nigeria	Retrospective chart/database review (incidence only)	84		1980–2000	Single hospital records†	Any	No	No	N/A	Maternal death, placental abruption, uterine rupture, C-section	Perinatal death (fetal death), fetal tachycardia

*National survey.
†Two hospitals in same region included.
‡Possible/probable/incapacitated/fatal.
§Fatal/major/minor/uninjured.
¶'Severe'= admission to ICU and/or blood transfusion and/or injury to abdomen/pelvis/lower back.
APH, antepartum haemorrhage; GW, gestational week; ICU, intensive care unit; ISS, Injury Severity Score; LBW, low birth weight; MVCs, motor vehicle crashes; N/A, not applicable; NASS/CDS, National Automotive Sampling System/Crashworthiness Data System; PPH, postpartum haemorrhage; PRAMS, Pregnancy Risk Assessment Monitoring System; PROM, premature rupture of membranes; RDS, respiratory distress syndrome; RTS, Revised Trauma Score; SGA, small for gestational age; UTI, urinary tract infection.

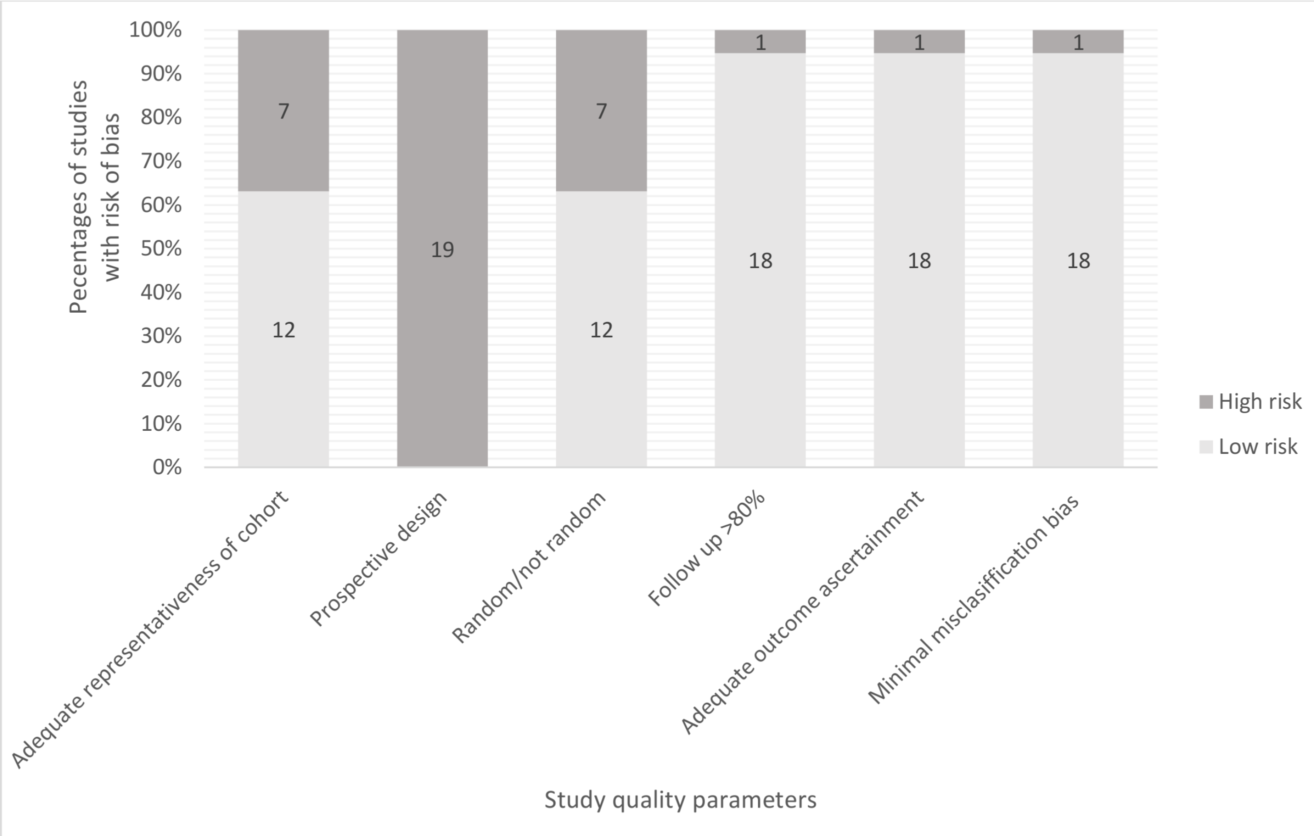

Figure 2 The quality assessment of the included studies.

preterm delivery, caesarean section, PROM and placental abruption (population level-data).

Strengths and weaknesses of this study

This is the second systematic review, after the one of Mendez-Figueroa *et al*,[4] looking at outcomes following MVC in pregnancy. We conducted our review using a prospectively registered protocol and reported it in accordance with the international standards.[41] This review, to our best knowledge, is the first one examining the link between involvement in MVC, mortality and adverse outcomes that involves evaluation of study quality assessment; 14 studies looking at outcome incidence related to MVC[2 17 29–40] and 5 studies comparing outcomes in pregnant women involved in MVC and those who were not.[6 8 26–28] We used established tools to assess outcome reporting quality for the incidence rates[42] and comparability.[23] We included data from population-level and single-centre studies, but the analysis and reporting of the results were independent in order to get precision and validity in the estimations. However, a couple of graphics of the maternal and offspring's outcomes incidences have been included as online supplemental appendices 3 and 4. Between August 2018 and March 2020, there have been no new studies eligible to include in the systematic review.

For the incidence analysis, we evaluated the quality of the 19 studies of this systematic review. The highest risk was in the design. None of the studies had a prospective design. The representativeness of cohort and the random method of sampling were other limitations of the quality of studies, with 7 out of 19 studies having a high risk of bias in these areas.[17 30 31 34 37 38 40] However, the quality assessment of the five papers included for comparison of complication rates between pregnant women involved and not involved in MVC using the Newcastle–Ottawa Scale showed generally high quality, with four papers scoring 9/9.[6 8 26 28]

The weaknesses of this systematic review are as follows. First, outcomes were not reported by trimester, with 13 out of 19 papers focused on MVC at any trimester. Second, outcomes, according to seat belt use, are scarce as only two studies using population-level data looked at safety features as a stratification factor.[8 26] Two studies with data sourced from hospital records/single-site trauma registries[37 38] and three studies using population-level databases[8 26 29] reported some outcomes regarding seat belt use. Third, we found a limited number of relevant studies comparing outcomes between women involved and not involved in MVC. The majority of the studies were carried out in the USA[8 26 28] with most recent one published in 2013.[8] Fourth, the included studies differed in study design with seven of them using hospital records/single-site trauma registry[17 30 31 34 37 38 40] and twelve population databases.[2 6 8 26–29 32 33 35 36 39] Despite analysing the data within the respective study designs and incorporation of anticipated variation into the statistical model (random-effects),[43] we encountered substantial statistical

Table 2 Incidence of adverse outcomes per 1000 women involved in motor vehicle crashes

Outcome and study	Number of studies	Number of women	Incidence estimate per 1000 women	95% CI
Maternal				
Maternal death	3	12 000	3.60	0.25–10.42
Azar *et al*,[2] 2005			6.57	4.68–8.97
Kvarnstrand *et al*,[27] 2008			6.61	3.70–10.88
Miller *et al*,[40] 2016			0.26	0.01–1.47
Admission to hospital	**2**	**3838**	**17.08**	**13.20–21.46**
Vivian-Taylor *et al*,[6] 2012			8.90	5.28–14.03
Weiss *et al*,[35] 2008			29.19	21.94–38.0
Placenta abruption	**6**	**36 737**	**16.14**	**7.04–28.78**
Wolf *et al*,[29] 1993			8.10	5.02–12.36
Miller *et al*,[40] 2016			1.05	0.29–2.70
Schiff and Holt,[28] 2005			113.40	88.80–142.01
Schiff *et al*,[36] 2010			12.25	8.80–16.58
Vivian-Taylor *et al*,[6] 2012			16.32	11.26–22.84
Vladutiu *et al*,[8] 2013			7.17	6.15–8.31
Preterm delivery	**5**	**265 680**	**191.90**	**45.98–405.74**
Schiff and Holt,[28] 2005			316.15	278.53–355.65
Schiff *et al*,[36] 2010			97.37	87.53–107.92
Vivian-Taylor *et al*,[6] 2012			83.09	71.42–95.98
Vladutiu *et al*,[8] 2013			110.33	106.43–114.33
Whitehead,[39] 2013			437.00	435.00–439.01
PROM	**3**	**260 310**	**42.33**	**5.87–109.24**
Schiff and Holt,[28] 2005			22.34	11.95–37.89
Vladutiu *et al*,[8] 2013			23.53	21.66–25.51
Whitehead,[39] 2013			96.00	94.81–97.20
Labour induction	**2**	**3930**	**276.43**	**262.54290.54**
Schiff and Holt,[28] 2005			223.37	190.15–259.42
Schiff *et al*,[36] 2010			286.14	270.87–301.78
Caesarean section	**5**	**12 338**	**166.65**	**47.34–339.00**
Miller *et al*,[40] 2016			6.06	3.85–9.08
Schiff and Holt,[28] 2005			254.30	219.38–291.73
Schiff *et al*,[36] 2010			259.26	244.48–274.46
Vivian-Taylor *et al*,[6] 2012			260.14	241.13–279.85
Wolf *et al*,[29] 1993			171.68	157.35–186.76
Offspring				
Perinatal death	**8**	**47 992**	**6.60**	**3.81–10.12**
Kvarnstrand *et al*,[27] 2008	Fetal/neonatal		17.62	12.62–23.92
Hyde *et al*,[26] 2003	Fetal		5.01	3.66–6.70
Miller *et al*,[40] 2016	Stillbirth		0.79	0.16–2.31
Schiff and Holt,[28] 2005	Fetal		12.03	4.85–24.62
Vivian-Taylor *et al*,[6] 2012	Stillbirth		16.82	11.67–23.42
Vladutiu *et al*,[8] 2013	Stillbirth		5.25	4.38–6.23
Schiff *et al*,[36] 2010	Fetal		4.18	2.29–7.01
Wolf *et al*,[29] 1993	Fetal		3.47	1.59–6.58

Continued

Table 2 Continued

Outcome and study	Number of studies	Number of women	Incidence estimate per 1000 women	95% CI
Fetal distress	**2**	**3930**	**60.09**	**52.85–67.77**
Schiff and Holt,[28] 2005			132.30	105.84–162.56
Schiff *et al*,[36] 2010			50.48	43.31–58.44
Meconium at delivery	**2**	**3930**	**52.61**	**45.82–59.85**
Schiff and Holt,[28] 2005			63.57	45.15–86.57
Schiff *et al*,[36] 2010			51.08	43.86–59.08
RDS	**3**	**6522**	**15.19**	**5.83–28.68**
Schiff and Holt,[28] 2005			32.65	19.77–50.51
Schiff *et al*,[36] 2010			14.64	10.85–19.30
Wolf *et al*,[29] 1993			6.17	3.53–10.00

Data source: population database
PROM, premature rupture of membranes; RDS, respiratory distress syndrome.

heterogeneity in the pooled estimates that could not be formally explored due to a limited number of studies and poor reporting of important factors such as trauma severity. As a fifth point, these data apply to developed countries—only one of the papers included data from an underdeveloped country, perhaps influencing the outcomes that might otherwise be seen in the developed world. Finally, in only eight studies did authors assess severity of MVC injuries, with only five of these using a validated tool.[28 30 34 37 40] This was a challenge when aiming to analyse results according to the severity of the crash.

Meaning of the study

The strongest association was found between placental abruption[6 8 28] and MVC. Maternal death was associated with involvement in MVC but this finding needs to be treated with caution as the data come from a single study.[27] The outcomes in descending order of incidence estimate per 1000 (population-level data) were the induction of labour, preterm delivery, caesarean section, PROM and admission to hospital, placental abruption and maternal death. In the analyses stratified by use of

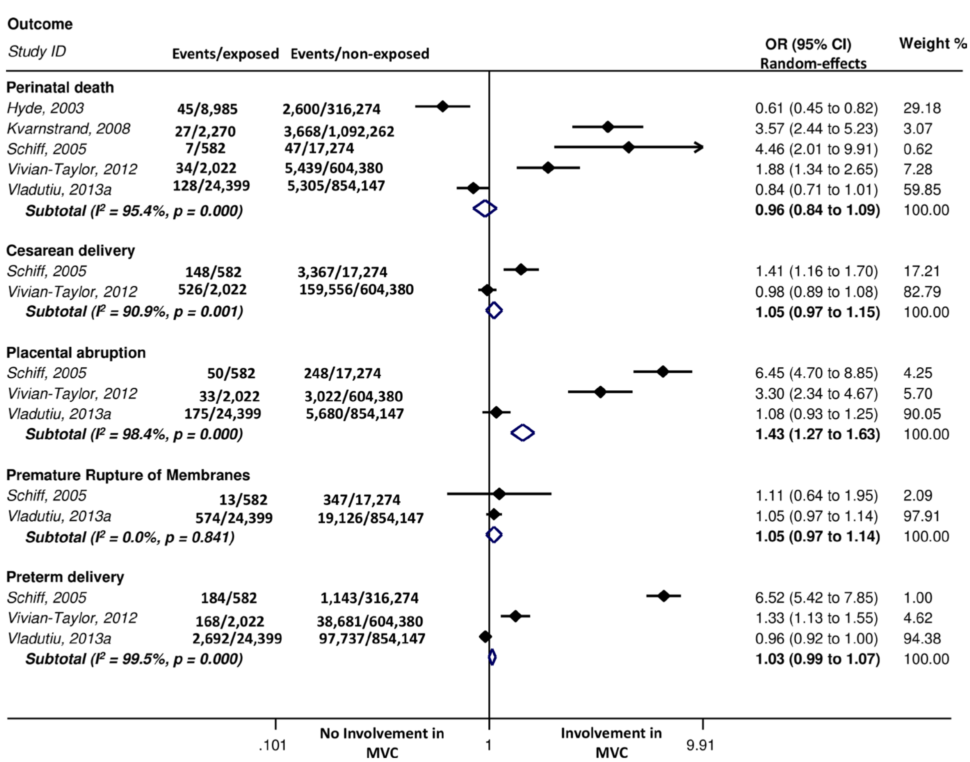

Figure 3 Comparison of outcomes between women involved and not involved in motor vehicle crashes (MVCs).

seat belts, we observed an association of fetal death with lack of seat belt use by pregnant women involved in an MVC. However, this finding was not statistically significant and informed by a limited number of studies. Previous studies have shown that pregnant women wearing seat belts during the MVC did not experience a significantly higher risk of adverse fetal outcomes than women who were not involved in MVC.[26] Furthermore, airbags seem to be contributing to the protection of both pregnant drivers and their fetuses.[44]

The results of this systematic review provide evidence informing primary prevention measures, recommendations and educational interventions for pregnant women in the context of MVC that should be incorporated into the primary care guidelines.

Unanswered questions and future research

The effects of MVC in pregnant women is a specific field that requires further research and an improved methodological approach to determine the risks of adverse maternal and fetal outcomes.

Additional variables such as trauma severity, the position of the women in the car, use of seat belts, deployment or non-deployment of an airbag, severity of the crash and gestational week of pregnancy should be recorded in relation to MVC exposure in order to allow more precision when analysing outcomes. A greater number of well-designed studies in a variety of global settings would strengthen current evidence-base.

CONCLUSIONS

Pregnant women involved in MVC seem to be at increased risk of maternal death and complications, especially placental abruption, than those not involved in MVC. The risk of complications such as preterm delivery, PROM and caesarean section were also increased. However, these findings need to be treated with caution due to the small number of studies included in the review and considerable differences between studies. Road traffic authorities should be conscious and strict in targeting preventive measures aimed at pregnant users of motor vehicles due to risk associated with potential involvement in MVC.

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