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Traumatic pelvic ring fracture during pregnancy: a systematic review

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- *Purpose*: This systematic review aims to investigate the management and outcomes of pelvic ring fractures (PRFs) during pregnancy, emphasizing maternal and fetal mortality rates, mechanisms of injury, and treatment modalities.
- *Methods*: Following PRISMA guidelines, we conducted a comprehensive search of databases from 2000 to 2023. This search identified 15 relevant studies involving a total of 33 patients. Data extraction included demographics, fracture types, treatment methods, and outcomes. Risk of bias was assessed using the JBI criteria.
- *Results*: Maternal mortality stood at 9.1%, with fetal mortality at 42.4%. Maternal factors impacting mortality included head trauma and hemodynamic instability. Fetal mortality correlated with mechanisms like motor vehicle accidents and maternal vital signs. Surgical and conservative treatments were applied, with a majority of pelvic surgeries performed before delivery. External fixators proved effective in fracture stabilization.
- *Conclusion*: Pelvic ring fractures during pregnancy present significant risks to maternal and fetal health. Early stabilization and vigilant monitoring of maternal vital signs are crucial. Vaginal bleeding/discharge serves as a critical fetal risk indicator. The choice between surgical and conservative treatment minimally influenced outcomes. Multidisciplinary collaboration and tailored interventions are essential in managing these complex cases.

Keywords: external fixators; fetal mortality; fracture types; maternal mortality; pelvic ring fractures; pregnancy; systematic review; treatment

Introduction

Pelvic ring fractures (PRFs) resulting from blunt trauma during pregnancy are a rare yet highly critical condition for both the mother and the fetus (1, 2, 3, 4, 5, 6, 7). The prevalence of PRFs among blunt trauma-induced fractures is reported to range from 5 to 8%. The associated mortality rates are reported as 9% for mothers and up to 60% for fetuses. This significant mortality rate is influenced

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by various factors. PRFs that lead to hypovolemia can independently escalate patient mortality, irrespective of underlying conditions. This risk is notably exacerbated in pregnant women that potentially elevate the likelihood of fatality (1, 5, 8, 9, 10, 11, 12, 13).

Regarding the fetus, factors such as placental injuries, depressed skull fractures, the need for blood transfusions, and maternal hypovolemia (which can lead to a reduction in placental blood supply by up to 20%, subsequently increasing the risk of fetal death) may contribute to fetal demise. A retrospective cohort study has documented that a surviving fetus from mothers with fractures is susceptible to negative consequences, including low birth weight, premature birth, and enduring neurocognitive dysfunction (1, 3, 14).

Previous studies have unveiled numerous uncertainties in the management of these patients. This systematic review endeavors to comprehensively analyze literatures concerning the management of PRFs during pregnancy, with a specific emphasis on treatment modalities and outcomes. By synthesizing existing evidence, our objective is to provide insightful guidance for clinical decision-making and elevate the quality of care extended to pregnant patients grappling with pelvic fractures.

Methods

The protocol for this systematic review was developed following the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (15). Furthermore, the protocol was registered in the International Prospective Register of Systematic Reviews.

A comprehensive search was conducted on databases including PubMed, Embase, Scopus, Web of Science, and Google Scholar until June 16, 2023, without language restrictions. The search terms encompassed keywords such as 'hip fracture', 'sacrum fracture', 'pregnancy', and others (Supplementary Table 1, see section on supplementary materials given at the end of this article). Inclusion criteria for this review are described in Table 1.

All articles were imported into Rayyan QCRI data management software (16). Duplicate records were removed by two collaborators. Four reviewers conducted blind assessments of titles and abstracts, with final admissions authorized by an expert supervisor.

The full text of all included articles was individually reviewed by three collaborators. Conflicts arising during screening and full-text review were resolved through reviewer discussions until consensus was reached. Data extraction was done using a standardized Microsoft Excel form, collecting information including publication year, study location, design, population characteristics, sample size, mean age, diagnosis types, treatment methods, outcome measures (pain, symptoms, functional outcomes), and additional relevant data.

In this review, PRF types were categorized using the Young–Burgess Classification. Two orthopedic specialists independently assessed each case, blinded to each other's evaluations. Their assessments were based on a detailed analysis of radiographs, CT scans, and fracture descriptions reported in the articles. To ensure the accuracy and consistency of classification, any discrepancies between the two assessments were resolved through a structured consensus process. This approach aimed to maintain the objectivity and reliability of the classification, with each case being reviewed until a unanimous agreement was reached.

Table 1 Inclusion and exclusion criteria.

	Inclusion criteria	Exclusion criteria
Population	Pregnant women with pelvic ring fractures	Studies not involving pregnant patients
Intervention	Studies reporting management strategies for pelvic ring fractures in pregnant patients	Studies involving pregnant patients with fractures unrelated to blunt trauma
Control	Not applicable (interventional studies, case reports, and case series)	Not applicable
Outcome	Studies reporting outcomes related to maternal and fetal health	Studies unrelated to pelvic ring fractures or not reporting management strategies for pregnant patients
Study design	Case reports and case series describing pelvic ring fracture management in pregnant women.	Studies with incomplete or insufficient data regarding pelvic ring fracture management in pregnant patients
Others		
Fracture	Studies reporting on traumatic pelvic ring fractures	Studies reporting on non-traumatic or stress pelvic fractures (e.g. osteoporosis, malignancy)
Language	Studies published in English	Studies published in languages other than English
Publication date	Studies published after January 1, 2000	Studies published before January 1, 2000

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Risk of bias assessment

The Joanna Briggs Institute (JBI) criteria were used as a framework for assessing the risk of bias (17). The risk of bias assessment was conducted independently by two researchers and any discrepancies were resolved through consensus or by consulting a third expert. The assessment results were summarized and reported for each included study, highlighting any potential biases that may affect the validity and reliability of the findings. This rigorous assessment provides a comprehensive evaluation of the risk of bias in the included studies and enhances the transparency and credibility of the systematic review.

Statistical analysis

Data synthesis was conducted through descriptive statistics exclusively. Categorical variables were elucidated using counts and percentages, while continuous variables were summarized employing mean and standard deviations.

Results

Study selection

The initial search yielded a total of 396 articles. After removing duplicates (*n* = 200), 196 articles remained for title and abstract screening. Following this screening, 28 articles were selected for full-text review. During the full-text review, 15 articles met the inclusion criteria and were included in the qualitative synthesis. Among them, 15 studies were eligible for quantitative analysis in the individual analysis. (18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32) (Fig. 1).

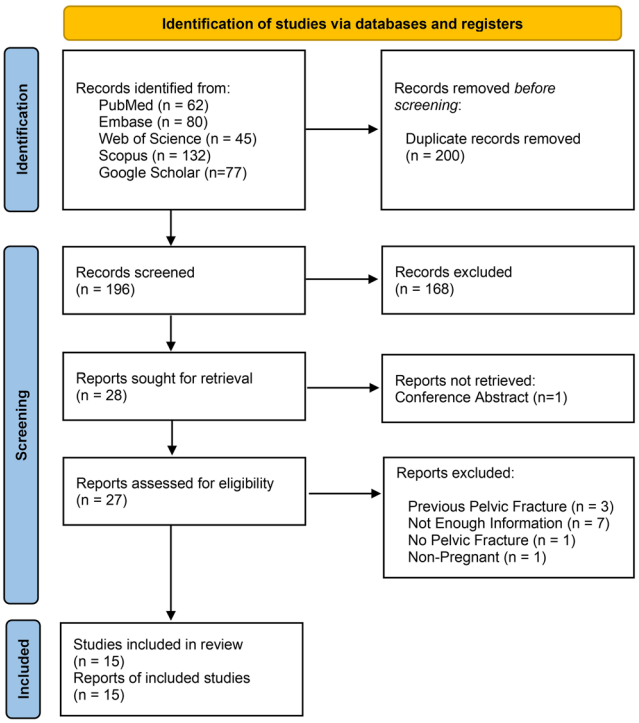

Figure 1

This flowchart illustrates the systematic literature search process conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) algorithm.

Characteristics of included studies

A total of 15 studies and 33 pregnant mothers who suffered PRFs were included based on the inclusion and exclusion criteria that the studies were from January 2000 to June 2023, of which three studies were in the form of case series (19, 22, 29) and 13 studies were in the form of case reports (18, 20, 21, 23, 24, 25, 26, 27, 28, 30, 31, 32). The average age of the mothers was 26.39 years (ranging from 15 to 40) with an S.D. of 7.26. The average gestational age was 22 weeks (ranging from 4 to 41) with an S.D. of 9.55.

Trauma mechanisms, fracture types, and stimulant fractures

Among the 33 trauma cases, 17 patients (63%) experienced motor vehicle accidents (MVA), while ten patients (37%) were involved in car-to-pedestrian accidents.

Out of 33 cases, ten cases have vertical shear (VS) damage (30.3%), seven (21.2%) have lateral compression (LC) type 1, and seven (21.2%) have anterior–posterior compression (APC) type 2. Additionally, four cases (12.1%) showed APC type 3 fractures, four cases (12.1%) had combined mechanisms, and one case (3%) presented with APC type 1 fracture.

The fetal mortality rates for different types of PRFs were observed as follows: 75% for combined types, 40% for VS, 50% for APC 3, and 42.9% for APC 2.

Out of the 33 patients, 16 cases (48.5%) had associated fractures. Most of these fractures were related to the acetabulum (seven cases) and femur shaft (four cases) (Table 3).

Maternal

Three out of 33 mothers (9.1%) died. All the maternal deaths were attributed to MVA.

Among the 29 mothers whose primary vital signs were reported, 19 cases (65.5%) had stable vital signs, out of which one patient died. The remaining ten cases (34.5%) had unstable vital signs, with two of them resulting in maternal death.

Initial state of consciousness was reported in 18 mothers, of which five cases (27.8%) were unconscious and two of these patients died. Out of eight cases with reported head injuries status, three

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cases (37.5%) experienced head injuries. Two cases of unconscious patients with head injuries resulted in one maternal death. Notably, one patient with a head injury died despite stable and alert vital signs.

Out of the 12 patients for whom the presence or absence of vaginal bleeding or discharge was reported, seven cases (58.3%) had vaginal bleeding or discharge, and one patient died with vaginal bleeding (Table 2).

Fetal

Out of the 33 fetuses, 14 (42.4%) did not survive, with three cases resulting from pregnancy termination. Of the fetuses that survived, two infants exhibited neurological or developmental disorders. In one case, any connection between brain damage and trauma was dismissed.

Of the 27 cases that reported the mechanism of trauma, 12 cases of fetal mortality were reported. MVA was the main mechanism leading to fetal death, with eight out of 12 fetal deaths (66.67%) attributed to MVA.

In 29 cases that reported the condition of the mother's vital signs, 12 fetuses died. Of these, five fetuses (41.7%) were reported to have unstable maternal primary vital signs, while seven (58.3%) had mothers with stable initial vital signs. In the latter group, three fetuses had

Table 2 Maternal and fetal outcomes in pregnant patients with pelvic ring fractures. Data are presented as *n* (%).

	Alive mother	Dead mother	Alive fetus	Dismissed fetus	Total
Trimester					
First	6 (85.7%)	1 (14.3%)	1 (14.3%)	6 (85.7%)	7 (100%)
Second	14 (93.3%)	1 (6.7%)	10 (66.7%)	5 (33.3%)	15 (100%)
Third	9 (90%)	1 (10%)	7 (70%)	3 (30%)	10 (100%)
Trauma mechanism					
MVA	14 (82.4%)	3 (17.6%)	9 (52.9%)	8 (47.1%)	17 (100%)
CTPA	10 (100%)	0 (0.0%)	6 (60%)	4 (40%)	10 (100%)
Vital signs					
Stable	18 (94.7%)	1 (5.3%)	12 (63.2%)	7 (36.8%)	19 (100%)
Unstable	8 (80%)	2 (20%)	5 (50%)	5 (50%)	10 (100%)
Neurological status					
Conscious	12 (92.3%)	1 (7.7%	6 (46.2%)	7 (53.8%)	13 (100%)
Unconscious	3 (60%)	2 (40%)	2 (40%)	3 (60%)	5 (100%)
Head injury					
No	5 (100%)	0 (0.0%)	3 (60%)	2 (40%)	5 (100%)
Yes	1 (33.3%)	2 (66.7%)	1 (33.3%)	2 (66.7%)	3 (100%)
Vaginal bleeding or discharge					
No	5 (100%)	0 (0.0%)	2 (40.0%)	3 (60.0%)	5 (100%)
Vaginal bleeding	2 (66.7%)	1 (33.3%)	1 (33.3%)	2 (66.7%)	3 (100%)
Vaginal discharge	4 (100%)	0 (0.0%)	1 (25.0%)	3 (75.0%)	4 (100%)
Placental injury					
Yes	–	–	1 (25.0%)	3 (75.0%)	4 (100%)
No	–	–	1 (33.3%)	2 (66.7%)	3 (100%)
Fetus arrival status					
Dead or no cardiac activity	–	–	0 (0.0%)	6 (100%)	6 (100%)
Decreased fetal cardiac activity	–	–	1 (33.3%)	2 (66.7%)	3 (100%)
Normal or healthy	–	–	11 (73.3%)	4 (26.7%)	15 (100%)
Delivery status					
Preterm delivery	6 (100%)	0 (0.0%)	6 (100%)	0 (0.0%)	6 (100%)
Term delivery	12 (100%)	0 (0.0%)	12 (100%)	0 (0.0%)	12 (100%)
Still birth delivery	11 (78.6%)	3 (21.4%)	0 (100%)	14 (100%)	14 (100%)
Delivery emergence					
Non-emergent delivery	–	–	15 (93.8%)	1 (6.3%)	16 (100%)
Emergent delivery	–	–	2 (40%)	3 (60%)	5 (100%)
Delivery method					
Vaginal	9 (100%)	–	8 (88.9%)	1 (11.1%)	9 (100%)
Cesarean section	13 (100%)	–	10 (76.9%)	3 (23.1%)	13 (100%)
Curettage	4 (100%)	–	0 (0.0%)	4 (100%)	4 (100%)

MVA, motor vehicle accidents.

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Table 3 Maternal and fetal outcomes in PRFs during pregnancy: an analysis by fracture type and management approach.

	Alive mother	Dead mother	Alive fetus	Dismissed fetus	Total
Associated fracture					
Yes	14 (87.5%)	2 (12.5%)	11 (68.8%)	5 (31.3%)	16 (100%)
No	16 (94.1%)	1 (5.9%)	8 (47.1%)	9 (52.9%)	17 (100%)
Pelvic ring fracture type					
LC-I	7 (100%)	0 (0.0%)	6 (85.7%)	1 (14.3%)	7 (100%)
APC-I	1 (100%)	0 (0.0%)	0 (0.0%)	1 (100%)	1 (100%)
APC-II	6 (85.7%)	1 (14.3%)	4 (57.1%)	3 (42.9%)	7 (100%)
APC-III	4 (100%)	0 (0.0%)	2 (50.0%)	2 (50.0%)	4 (100%)
VS	8 (80%)	2 (20%)	6 (60%)	4 (40%)	10 (100%)
Combined	4 (100%)	0 (0.0%)	1 (25%)	3 (75%)	4 (100%)
Overall pelvic management					
Conservative	12 (100%)	0 (0.0%)	8 (66.7%)	4 (33.3%)	12 (100%)
Surgical	18 (90.9%)	3 (9.1%)	11 (52.4%)	10 (47.6%)	21 (100%)
Pelvic management method					
Conservative	12 (100%)	0 (0.0%)	8 (66.7%)	4 (33.3%)	12 (100%)
External fixator	5 (62.5%)	3 (37.5%)	3 (37.5%)	5 (62.5%)	8 (100 %)
Symphyseal plating	5 (100%)	0 (0.0%)	4 (80.0%)	1 (20.0%)	5 (100%)
Iliosacral plating	1 (100%)	0 (0.0%)	1 (100%)	0 (0.0%)	1 (100%)
External fixator and sacroiliac fixation	1 (100%)	0 (0.0%)	1 (100%)	0 (0.0%)	1 (100%)
ORIF of symphysis and sacroiliac joint	3 (100%)	0 (0.0%)	0 (0.0%)	3 (100%)	3 (100%)
External fixator and ORIF of sacroiliac joint and lumbopelvic fixation	1 (100%)	0 (0.0%)	1 (100%)	0 (0.0%)	1 (100%)
ORIF but specific method not mentioned	2 (100%)	0 (0.0%)	1 (50%)	1 (50%)	2 (100%)
Time of pelvic surgery					
Before delivery	13 (81.3%)	3 (18.8%)	8 (50.0%)	8 (50.0%)	16 (100%)
After delivery	5 (100%)	0 (0.0%)	3 (60%)	2 (40%)	5 (100 %)

APC, anterior–posterior compression; LC, lateral compression; ORIF, open reduction and internal fixation; VS, vertical shear.

pregnancies terminated. Out of ten mothers whose primary vital signs were unstable, five fetuses survived.

Out of 18 cases reporting maternal consciousness status, 13 mothers were conscious. Of these conscious mothers, seven fetuses (53.8%) did not survive. Out of the five unconscious mothers, three fetuses (60%) did not survive.

Among the eight mothers for whom the presence or absence of head trauma was reported, two fetuses of mothers with head trauma experienced mortality, and likewise, two fetuses of mothers without head trauma also faced mortality.

Out of seven mothers with vaginal bleeding or discharge, five cases (71.42%) experienced fetal death. Among the eight cases reporting placenta conditions, five cases of placental injury were observed. Out of these, four fetuses (80%) did not survive and one fetus was reported to be alive but unhealthy. Furthermore, three cases of placental injury accompanied by vaginal bleeding have been reported. From these three, two cases resulted in fetal mortality, while one case indicated the fetus being born in an unhealthy condition.

In total, 24 cases have reported the condition of the fetus at arrival, six fetuses had no cardiac activity upon arrival. Three cases had decreased fetal cardiac activity, and from these, two fetuses did not survive, while one was reported as alive but unhealthy. Notably, all of these cases were in the third trimester.

Additionally, 15 fetuses were reported to have a normal sonography upon arrival. However, four of these fetuses did not survive, and notably, one of these cases resulted in the decision for termination of pregnancy.

Of the six fetuses (27.3%) that did not survive upon arrival, two were in the first trimester and four were in the second trimester. In one case involving a fetus at the 32nd week of GA, the initial sonography indicated normal findings. However, the fetus did not survive in the end.

Of the six fetuses that did not survive upon arrival, three mothers had abnormal vital signs, and in two cases, the mothers were unconscious upon arrival.

Out of six fetuses that did not survive upon arrival, three mothers had vaginal bleeding or discharge, and two of these cases were associated with placental injury.

Furthermore, among the six fetuses that did not survive upon arrival, four mothers had additional fractures such as acetabulum, femur shaft, and others (Table 2).

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Pelvic management

Pelvic management method

Out of the 33 mothers with pelvic fractures, 12 were managed conservatively, while 21 underwent various surgical treatments.

Regarding the 21 mothers who underwent surgical treatments, three mothers died, and out of these, 10 (48%) fetuses also died.

Out of the 33 mothers with pelvic fractures, 12 were managed conservatively. Among those managed conservatively, 33.33% of their fetuses did not survive (Table 3).

Pelvic binders were utilized in three cases of PRFs during pregnancy, with two of these instances specifically involving emergency stabilization.

Surgery method and time of pelvic surgery

Out of 21 patients who underwent surgery, 16 cases underwent pelvic surgery before delivery, in which eight (50%) fetuses died and three mothers also died.

Out of the 21 patients who underwent surgery, the distribution of management approaches was as follows:

1. **External fixator**

   Eight patients were managed with external fixator, and all eight of these cases involved the use of the external fixator before delivery. And all eight items were applied before delivery. Among these cases, there were five fetal deaths and three maternal deaths. Additionally, two of the mothers were in unstable condition upon their arrival for medical care.

2. **Symphyseal plating open reduction and internal fixation**

   Five patients were managed with symphyseal plating open reduction and internal fixation (ORIF). In one case, the fetus did not survive. Three mothers underwent surgery after delivery.

3. **ORIF of both symphysis and sacroiliac joint**

   Three cases underwent ORIF of both symphysis and sacroiliac joint before delivery. All the fetuses did not survive this treatment method. Two of them died before the surgery, and in the third case, pregnancy termination was performed despite the fact that the embryo was viable.

4. **Anterior external fixator and the sacroiliac joint and lumbopelvic fixation**

   One case received a combination of external fixator and the sacroiliac joint and lumbopelvic fixation which was done before delivery and the fetus survived.

5. **Anterior external fixator and the sacroiliac joint fixation**

   One case received a combination of external fixator and the sacroiliac joint fixation which was done before delivery and the fetus survived.

6. **Iliosacral plating**

   One case underwent iliosacral plating which was done before delivery and the fetus survived.

7. Additionally, two cases had ORIF procedures, but the specific type was not mentioned in the available data. In both cases, surgery was performed after delivery.

Conservative management was chosen for 85.71% of LC type 1 fractures (six out of seven cases). Symphyseal plating was performed in 45.45% of APC types 2 and 3 fractures, with one such case also involving sacroiliac joint fixation. Additionally, 36.36% of APC type 2 and 3 fractures were treated with external fixators. Among VS fractures, non-surgical treatment was opted for in 10% of cases (one out of ten patients), while 40% underwent various surgical methods. Moreover, a case of a combined fracture was managed using an external fixator (Table 3).

Pelvic outcome

In our systematic review, the follow-up for PRFs was reported in 19 studies, encompassing 33 cases. The follow-up duration for PRFs had a median of 13 months, with a range of 2 to 180 months. The mean duration was 42.68 months, and the standard deviation was 55.401. Out of the 21 studies reporting on pelvic outcomes, 57.1% (12 studies) indicated patients experienced no pain with a normal range of motion. Another 38.1% (8 studies) reported no functional limitations in patients. Remarkably, only 4.8% (1 study) documented a patient with a painful range of motion, which was managed conservatively (Table 3).

Delivery

In five studies, emergent delivery was performed due to fetal conditions, such as fetal heart rate reduction, and from these, three fetuses did not survive. Of the 18 fetuses that survived, 12 were full-term and six were pre-term. In 26 studies concerning delivery methods and pregnancy termination, it was reported that 13 cases involved cesarean section (C/S), nine cases had vaginal delivery, and four cases were terminated by curettage.

Bias assessment

The bias assessment for case reports and case series within the JBI literature involved a systematic

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evaluation across multiple domains. In the case reports, demographic characteristics and patient history were consistently described without bias. However, variations emerged in clinical condition presentation, adverse event reporting, and the completeness of intervention outcomes. While minor biases were noted, the case reports were deemed suitable for inclusion. For case series, well-defined inclusion criteria, standard measurement practices, and valid identification methods were consistently adhered to, reducing bias. However, bias was introduced through incomplete reporting of clinical information, outcomes, clinic demographics, and inadequate statistical analysis. Despite these biases, the case series could potentially be included in the review, with a need for awareness regarding these limitations (Supplementary Tables 6 and 7).

Discussion

In this systematic review focusing on PRFs during pregnancy, we uncovered significant complications associated with this condition. Our analysis revealed that PRFs in pregnant women are accompanied by a substantial maternal mortality rate of 9% and a fetal mortality rate of 42.4%, underscoring the severity of this medical challenge. MVAs emerged as the leading cause of these fractures. Furthermore, our investigation identified critical maternal factors such as hypovolemia, head injuries, and vaginal bleeding, which have a profound impact on both maternal and fetal outcomes. These findings emphasize the urgent need for tailored and individualized treatment strategies to effectively manage the complexities associated with PRFs during pregnancy.

Trauma during pregnancy significantly increases the risk for both mothers and fetuses. Recent studies reveal that pregnant trauma patients experience a notably higher mortality rate compared to non-pregnant individuals (2, 33, 34, 35). Retrospective cohort analyses have shown that in certain cases, the mortality rate is nearly double that of their non-pregnant counterparts (36). Among various injuries, those involving pelvic fractures are particularly associated with increased risk. PRFs, though rare in pregnancy, pose distinct challenges due to the physiological and anatomical changes in pregnant women. The substantial energy required to cause such fractures further heightens the risk, leading to escalated maternal and fetal mortality and morbidity (1, 10, 37, 38).

In 2002, Leggon *et al.* conducted a comprehensive review of studies that reported pelvic fractures in pregnant patients from 1966 to 2000 (5), while we examined the studies after 2000. Also, in 2018, Weinlein *et al.* conducted a retrospective study on 44 pregnant patients who suffered pelvic ring and acetabular fractures (13). Some of the results of these two studies were consistent, and some of these results were in conflict with our results.

In our observations, 63% (17 patients) experienced MVA, aligning with Leggon *et al.*'s review study in 2002. Notably, MVA was the predominant mechanism of injury, accounting for 73% of cases, and was also the most common mechanism reported in Weinlein's study (93%) (5, 13).

Our results showed that the maternal mortality rate was 9.1%, consistent with the 9% rate reported in Leggon's review study and the 2% rate in Weinlein's study (both studies included cases with acetabular fractures). Regarding fetal mortality, we observed a rate of 42.4%, while Leggon's study reported 35% and Weinlein's study reported 40% fetal mortality rates. The distribution of fetal deaths in our review was 42.9% in the first trimester, 35.7% in the second trimester, and 21.4% in the third trimester (P = 0.040). Although our results aligned with Weinlein's findings, they were not reported as statistically significant (13). However, in Leggon's study, it was found that most of the fetal mortality occurred in the third trimester (5).

The management of PRFs during pregnancy is a complex and multidisciplinary process that requires meticulous consideration to optimize both maternal and fetal health outcomes. This approach comprises three primary components. Initially, the primary management focuses on ensuring the mother's health and survival, as it is pivotal for the well-being of both mother and fetus. This involves stabilizing the mother, while concurrently monitoring fetal health through fetal heart rate monitoring and tocometry, without hindering resuscitative efforts. Subsequently, in the secondary survey, the medical team must evaluate and decide on the most appropriate diagnostic and management strategies for the fracture, while also conducting additional assessments of fetal well-being. Lastly, healthcare professionals need to determine the best course of action for the rest of the pregnancy in conjunction with the fracture management strategy (3, 8, 11, 39, 40).

As with any major trauma, ensuring the initial stabilization of both the mother and the fetus is paramount. Advanced Trauma Life Support algorithms (ABCDEF, with airway, breathing, circulation, disability (in the obstetric trauma patient, 'D' also stands for 'displacement'), exposure, and 'F' for fetus in obstetric trauma) should guide the initial actions (11, 41). Given the potential for significant blood loss in PRFs, especially when accompanied by other injuries like retro- and intraperitoneal injuries, vascular injuries within the pelvis, or fractures of long bones like the femur shaft, maintaining stable hemodynamics through hydration and oxygenation is critical (3, 8, 9, 10, 14, 32). Among the four mothers who had femoral shaft fractures, two did not survive (19). This highlights the critical importance of closely monitoring and providing prompt medical attention to mothers who experience femoral shaft fracture.

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We found that approximately 25% of mothers with unstable vital signs died, whereas the mortality rate was about 6% for mothers with stable vital signs. For fetuses, the mortality rate was 100% when mothers had unstable vital signs, compared to around 58% for fetuses with mothers exhibiting stable vital signs. Although these differences lacked statistical significance, they underscore the critical importance of early resuscitation and stabilization of vital signs for favorable maternal and fetal outcomes.

One of the primary factors contributing to the challenge of achieving an effective response during initial resuscitation in patients with PRFs is pelvic instability. To tackle this issue, the utilization of a pelvic binder emerges as a critical primary intervention, particularly in instances involving APC fractures. These fractures constituted 36.36% of the cases in our review. However, it is crucial to note that while a pelvic binder can offer stabilization, its application may inadvertently exert additional pressure on the gravid uterus, potentially leading to compression of the inferior vena cava. This could result in a decrease in venous return to the heart and subsequently impact cardiac output. Thus, the decision to apply a pelvic binder should be made with a careful assessment of the potential impact on both maternal and fetal circulatory dynamics (3, 8, 42). In the second half of pregnancy (when the uterus is palpable at or above the umbilicus), a left lateral tilt positioning is recommended to displace the gravid uterus 15–30° away from the main retroperitoneal blood vessels. This helps improve central circulating volume and cardiac output for better patient management (11).

Head trauma poses a significant risk for maternal mortality. In our analysis, two out of the eight mothers with reported head trauma experienced fetal deaths, as did two fetuses whose mothers had no head trauma. This finding correlates with those of Weinlein *et al.*'s study, which highlighted severe head injury in a deceased mother, and Leggon *et al.*'s study, which emphasized head trauma as a significant factor in fetal death (5, 13).

In our systematic review, among the three mothers who died, two patients were unconscious at the initial time of the injury, and in three cases of dead fetuses, the mothers were also unconscious. The study conducted by Weinlein *et al.* also reported that the deceased mother had suffered from a severe head injury (13). Additionally, the study by Leggon *et al.* highlighted head trauma as one of the significant factors contributing to fetal death (5). These findings emphasize the importance of considering head injuries and the primary level of consciousness in pregnant patients with pelvic fractures, as they can have substantial implications for both maternal and fetal outcomes.

We observed that 75% (three out of four cases) of the patients with placenta injury also presented with abnormal vaginal bleeding or discharge. Among them, two fetuses did not survive. This underscores the significance of closely monitoring vaginal bleeding or discharge during the initial examination of the mother. Such symptoms can indicate not only an open fracture (vaginal damage) but also damage to the amniotic sac or placenta previa or even placental injury, all of which pose a significant threat to the life of the fetus (3, 4, 5, 13, 42, 43, 44, 45, 46, 47, 48, 49).

When pregnant women present with hemodynamic instability, the initial assessment should include focused assessment sonography for trauma (FAST) to identify possible bleeding sources (50). While computerized tomography (CT) scan is highly sensitive and specific, FAST is the preferred initial diagnostic tool due to its non-invasive nature and safety (51). If bleeding is not detected by FAST, a CT scan is necessary, even though it exposes the patient to higher radiation. CT should not be avoided if essential for managing the mother's injuries (50). In cases of major bleeding observed on CT, angiography with or without pelvic arterial embolization can be performed to control hemorrhage (50). While this intervention should be used cautiously in pregnant trauma patients, it is not to be avoided when indicated (52). Laparotomy, pelvic packing, or external fixator placement in the operating room should be considered when major bleeding is evident or if the patient is unresponsive to resuscitation (42, 49) (Fig. 2).

In our review, C/S was performed in 13 cases. Four of these cases were treated conservatively, while surgery was performed in nine patients. Among the patients who underwent surgery, 56% had the surgery before delivery, and in all these cases, the fetus survived. In nine cases with vaginal delivery, the pelvic fracture of six mothers was managed conservatively, and three cases were managed surgically. All three cases were operated on before delivery, and, in one of them, the fetus did not survive. In Leggon's review study, it was reported that 75% of mothers had a successful vaginal delivery (5). The management approach for these patients, either conservative or surgical, was not specified in the study. Additionally, the study did not mention whether surgery was performed before delivery or not.

Emergent delivery was performed in five cases due to fetal conditions such as placental injury (three cases) and decreased fetal heart rate (two cases), and from these, three fetuses did not survive. It should be kept in mind that in the condition that the fetus is viable (greater than and equal to 20 weeks), in case of any doubts about the health condition of the fetus, taking into account the stability of the mother, emergent C/S should be considered. And in order to achieve faster stability of the mother in cases of unstable fractures, external fixators can be used as an available device with the possibility of very fast installation.

The highest fetal mortality rate was observed in mothers who had VS, APC type 2 and 3, and combined fractures. In contrast, according to Weinlein's study, fetal mortality was predominantly associated with LC type 1

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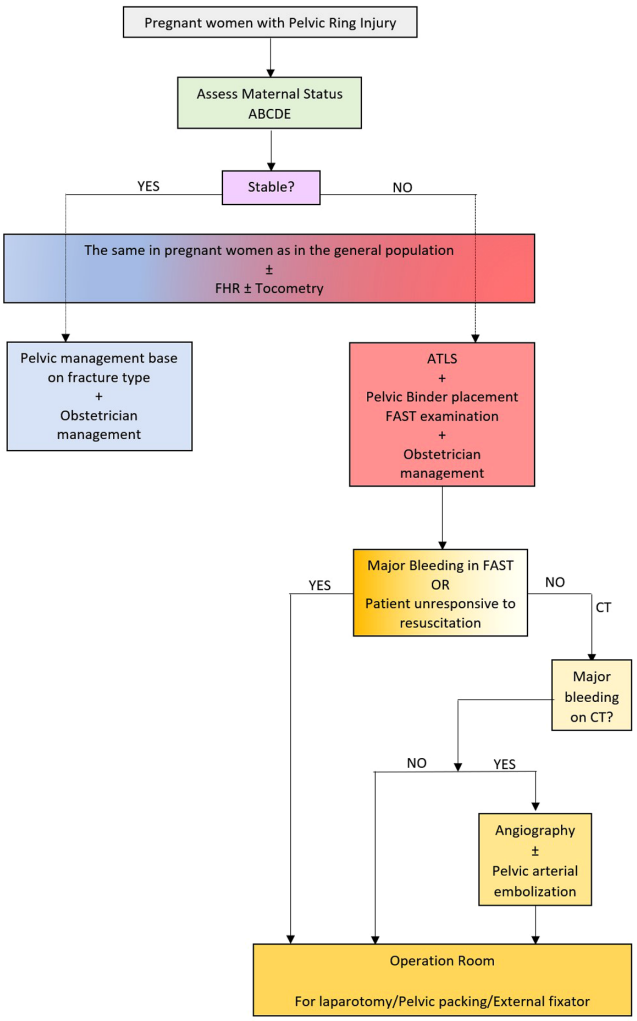

Figure 2

Algorithm for the initial management of pregnant patients with pelvic ring fractures (PRFs) in trauma care. In the context of managing pregnant patients with PRFs, the primary objective during the initial assessment is to conduct a primary survey. The foremost priority is to optimize the maternal hemodynamics and ensure an adequate oxygen supply. The initial approach to fetal well-being involves prioritizing the optimal resuscitation of the pregnant woman. Fetal evaluation should be performed as part of a secondary examination (11, 40). The standard trauma assessment follows the ABCDEs (airway, breathing, circulation, disability or displacement, exposure). Simultaneously, obstetrician providers should perform fetal heart rate (FHR) monitoring, and when gestational age is greater than or equal to 20 weeks, tocometry can also be considered. These evaluations should be conducted without disrupting the ongoing maternal resuscitation, in addition to addressing semi-traumatic and orthopedic considerations (3, 11, 40). If the mother's condition is stable, the management plan should be coordinated by the obstetrician team based on gestational age and by the orthopedic team based on the type of fracture (3, 11, 40). In cases where the patient's condition is unstable, adherence to the Advanced Trauma Life Support (ATLS) protocol is essential, along with the application of a pelvic binder and focused assessment with sonography for trauma (FAST) ultrasound. In situations where the fetus is viable, the obstetric team can continue fetal assessment concurrently with the trauma team's interventions. If the FAST ultrasound yields positive findings or patient unresponsive to resuscitation, immediate transfer to the operating room is imperative, allowing for timely interventions such as laparotomy, pelvic packing, and external fixator placement (3). If the FAST ultrasound results are negative, regardless of pregnancy status, contrast-enhanced pelvic computed tomography (CT) should be performed. This step ensures that in the presence of a substantial hematoma or arterial extravasation, appropriate measures like arterial embolization, laparotomy, pelvic packing, and external fixator application can be promptly initiated (3).

fractures, with a note that the number of cases related to other fracture types in their study was limited (13). Furthermore, Leggon *et al.*, did not find a significant relationship between the type of pelvic fracture and fetal mortality (5).

The high rate of conservative management in 86% of type 1 LC fractures suggests a preference for less invasive treatments when feasible. In contrast, more complex type 2 and 3 APC and VS fractures predominantly required surgical interventions, indicating a different approach in managing these more severe injuries. This variation in treatment strategies highlights the importance of tailoring medical decisions to the specific type and severity of fractures. While patients who were managed conservatively demonstrated a lower rate of fetal and maternal mortality, it's essential to consider that in these studies, a majority of patients underwent surgery with a higher rate of pelvic displacement. Consequently, the extent of initial trauma was more severe. Hence, it can be anticipated that the initial mortality rate of both the mother and fetus would be higher in these cases.

The management of PRFs in pregnant patients is crucial for both fracture and pregnancy management. This importance remains regardless of the pregnancy's progression or outcomes, including scenarios requiring pregnancy termination. The study by Xiao *et al.* highlights specific challenges, such as patient positioning for surgical procedures like curettage before PRF surgery (28). These complexities underscore the necessity for meticulous and specialized treatment plans, considering both the orthopedic and obstetric aspects of care in these sensitive cases.

Regarding the outcome of PRFs during pregnancy, the reviewed studies did not consistently report the same criteria. However, in one study, a patient experienced a painful range of motion following conservative treatment (22), while the remaining studies indicated patients achieved a favorable functional status with minimal or no pain.

The choice of management for PRFs (either conservative or surgical) did not result in a significant effect on maternal and fetal mortality. However, to establish more reliable outcomes, studies with a larger sample size are imperative.

The role of external fixators in the initial management of PRFs, especially for stabilizing patients with hemodynamic instability resulting from pelvic injuries,

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is a well-established practice in general trauma care (3). While our review did not specifically investigate this aspect, the consideration of external fixators for pregnant patients experiencing hemodynamic instability may offer potential benefits in stabilizing their condition. Nevertheless, further research is needed to definitively establish the efficacy and safety of this approach within the specific context of pregnancy and pelvic instability.

Conclusion

Our systematic review highlights maternal and fetal mortality rates of 9.1% and 42.9%, respectively. Elevated mortality was linked to factors such as head trauma, decreased consciousness, and hemodynamic instability in mothers. Notably, vaginal bleeding and discharge emerged as crucial indicators of fetal risk in pelvic fractures. While primary high-energy trauma often entails inevitable complications, our findings emphasize the pivotal role of the initial survey in shaping outcomes. Among these strategies, the creation and maintenance of pelvic ring stability, an essential facet of which involves orthopedic surgeons within the multidisciplinary team, contribute to better initial results. In instances where maternal and fetal lives are not directly threatened by pelvic instability, and emergency external fixator implantation is not warranted, pelvic ring surgery for these patients seems comparable to non-pregnant women.

Supplementary materials

This is linked to the online version of the paper at https://doi.org/10.1530/EOR-23-0164.

Additional information, including complete search terms, study characteristics, arrival status of both the mother and fetus, details of PRFs treatment, outcomes for both the mother and fetus, associated fractures, results of risk of bias assessments, and a list of studies excluded during the full-text screening stage, can be found in the supplementary file.

ICMJE Conflict of Interest Statement

Each author certifies that there are no funding or commercial associations (consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article related to the author or any immediate family members.

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