Eur J Trauma Emerg Surg (2019) 45:383–392
DOI 10.1007/s00068-017-0839-x

REVIEW ARTICLE

Traumatic injuries to the pregnant patient: a critical literature review

P. Petrone[1,2,3] · P. Jiménez-Morillas[1] · A. Axelrad[1] · C. P. Marini[3]

Received: 11 April 2017 / Accepted: 12 September 2017 / Published online: 15 September 2017

Abstract
Introduction Trauma during pregnancy is the leading non-obstetrical cause of maternal death and a significant public health burden. This study reviews the most common causes of trauma during pregnancy, morbidity, and mortality, and the impact upon perinatal outcomes associated with trauma, providing a management approach to pregnant trauma patients.
Materials and methods A systematic review of the current literature from January 2006 to July 2016 was performed.
Results Fifty-one articles were identified, including a total of 95,949 patients. Motor vehicle crash was the most frequent cause of blunt trauma, followed by falls, assault both domestic and interpersonal violence, and penetrating injuries (gunshot and stab wounds).
Conclusions Trauma in pregnant women is associated with high rates of adverse maternal and neonatal outcomes. Knowledge of the mechanism of injury is important to identify the potential injuries and the complexity of the management of these patients. As in all traumatic events, prevention is of paramount importance.

Keywords Trauma · Pregnancy · Fetal injuries · Blunt · Penetrating

✉ P. Petrone
patrizio.petrone@gmail.com; ppetrone@nyuwinthrop.org

[1] Department of Surgery, NYU Winthrop Hospital, 222 Station Plaza North, Suite 603, Mineola, Long Island, NY 11501, USA

[2] Universidad de Las Palmas de Gran Canaria, Las Palmas, Spain

[3] New York Medical College, Valhalla, USA

Introduction

Trauma is the leading non-obstetrical cause of maternal death during pregnancy. However, it may be an underestimation of the true incidence of trauma during pregnancy due to the under-reporting of trauma, especially trauma from interpersonal violence [1]. The aim of this article is to review the literature regarding trauma during pregnancy focusing on the most common mechanisms of injury, and maternal and fetal outcomes.

Materials and methods

Articles in the English language between January 2006 and July 2016 on trauma during pregnancy were identified using the following key words: trauma and pregnancy, blunt trauma, penetrating wound, injury during pregnancy, motor vehicle accident/crash, falls, assault, interpersonal violence, fetal monitoring, perimortem cesarean section, obstetrical patient, pregnant trauma patient, and mortality and pregnancy.

Results

Of the 200 articles identified, 51 were included in this study for a total of 95,949 patients.

Blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy. In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury. Mortality occurred in 100 of 728 (13.7%) mothers

and 78/728 (10.7%) fetuses. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was reported mechanism of injury, which ranged from a low of 21% to high value of 98%.

The second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women. During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures.

Table 1 includes the total number of patients stratified by the mechanism of injury, whereas Table 2 reports prevalence rates based on the causes of trauma. Maternal and fetal mortality rates have been derived from 28 of the 51 articles that included maternal and fetal mortality data (Table 3).

Epidemiology

Trauma is the leading cause of death in pregnant women, and it is responsible for a high rate of maternal and fetal morbidity. While the reported rate of complications of pregnancy due to trauma appears low, this rate is likely underestimated due to under-reporting particularly in cases of domestic violence [1].

Based on our review, blunt trauma is the most common mechanism of trauma among pregnant women accounting for 69% of the total number of traumas, whereas penetrating trauma accounts for only 1.5% of episodes of trauma during pregnancy (Table 1). Among the causes of blunt trauma, MVC is the most frequent cause of injury followed by falls, assault, gunshot, and stab wounds (Table 2). The severity of gravid uterus injuries is graded using the Organ Injury Scale of the American Association for the Surgery of Trauma (AAST-OIS) [54] (Table 4).

In a review of 102 trauma pregnant patients by Zangene et al. [38], blunt trauma was found to be the cause of trauma in 68% of pregnant women compared to 32% who had penetrating trauma. The most common mechanism of injury was MVC followed by domestic violence. The traumatic event caused maternal injuries, mostly lower extremity injuries, in 67% of patients, and it was associated with a 13% incidence of fetal complications [placental abruption (PA) and preterm]. Wall and others [39] have reported blunt trauma as a MOI in 57% of all cases compared to 21% where the MOI was penetrating

Table 1 Mechanisms of injury

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Metz (2006) [2]	30	30	0
El Kady (2006) [3]	3292	3292	0
Barré (2006) [4]	95	95	0
Aniuliene (2006) [5]	372	312	60
Weintraub (2006) [6]	54	54	0
Sperry (2006) [7]	151	NS	8
Hitosugi (2006) [8]	135	135	0
Kuo (2007) [9]	16,982	7100	335
Aboutanos (2007) [10]	294	259	NS
Greene (2007) [11]	352	NR	NR
Patteson (2007) [12]	188	NR	4
Kvarnstrand (2008) [13]	2270	2270	0
Weiss (2008) [14]	7350	3939	739
Cahill (2008) [15]	317	NR	NR
Klinich (2008) [16]	57	57	0
Aboutanos (2008) [17]	148	148	0
Schiff (2008) [18]	693	693	0
Nannini (2008) [19]	1468	1468	0
Dunning (2010) [20]	1070	1070	0
Cannada (2010) [21]	65	65	0
Tinker (2010) [22]	490	NR	NR
Vladutiu (2010) [23]	34	34	0
Schiff (2010) [24]	3348	3348	0
Petrone (2011) [1]	321	292	29
Preeti (2011) [25]	3763	NR	121
Vivian-Taylor (2012) [26]	2147	2147	0
Fischer (2011) [27]	5352	NR	NR
Lin (2011) [28]	27	NR	18
Meuleners (2011) [29]	468	468	0
Melamed (2012) [30]	411	411	0
Karadas (2012) [31]	139	NR	NR
Mesdaghinia (2012) [32]	32	32	0
Njoku (2013) [33]	63	56	5
Luley (2013) [34]	126	126	0
Vladutiu (2013) [35]	25,168	25,168	0
Periyanayagam (2014) [36]	635	NR	NR
Brookfield (2013) [37]	351	284	67
Zangene (2014) [38]	102	69	33
Wall (2014) [39]	42	24	9
Okeke (2014) [40]	108	108	0
Harland (2014) [41]	1488	372	NR
Ibrahim (2015) [42]	819	819	0
Chibber (2015) [43]	728	728	0
Jackson (2015) [44]	36	36	0
Azar (2015) [45]	5936	5936	0
Van der Knoop (2015) [46]	16	16	0
Shakerian (2015) [47]	74	74	0
Weiner (2016) [48]	946	946	0
Miller (2016) [49]	3794	3794	0
Battaloglu (2016) [50]	173	164	9

Table 1 (continued)

Author (year)	Total *n*	Blunt *n*	Penetrating *n*
Distelhorst (2016) [51]	3429	NR	NR
Total	95,949	66,439 (69%)	1437 (1.5%)

NR not recorded, *NS* not specified

trauma. Of note, in this study, interpersonal violence was the most common cause of injury followed by MVC, 52 and 26%, respectively. Fetal deaths occurred in 90% of patients with severe injuries (ISS > 15) and urgent laparotomy was required in 86% of women presenting with direct trauma to the abdomen.

In 37 articles reviewed herein, MVC is not only the most common but also the most life-threatening of mechanisms on injury [12]. Chibber et al. [43] have reported that 647 of 728 (89%) pregnant women involved in MVC presented with maternal and fetal complications (placental and preterm labor, 59 and 40% respectively). Mortality occurred in 100 of 728 (13.7%) mothers and 78/728 (10.7%) fetuses. Ninety-one perimortem cesareans sections were performed with a maternal mortality of 66% (60/91) and a much lower fetal mortality rate, 18.6% (17/91).

Vivian-Taylor et al. [26] have reported a series of 2147 pregnant women involved in MVC. In 72 of 2147 (3.3%) patients, the traumatic event caused delivery during the trauma hospitalization, five (7%) of whom suffered pelvic fractures, six (8%) presented intra-abdominal injuries, and seven (10%) were admitted to the ICU, three of whom subsequently died. They concluded that the injuries from an MVC during pregnancy are independent risk factors for induced delivery with poor perinatal outcomes.

The association of maternal fractures and perinatal outcomes has been investigated in a retrospective cohort study of 3292 pregnant women by El Kady et al. [3]. In their cohort study, fractures were identified in 44% of pregnant patients involved in an MVC. Pelvic fractures increased the morbidity and mortality not only of mothers, but also of fetuses. Aboutanos [17] reported a 48-fold increase in fetal death in patients with pelvic and acetabular fractures from MVC. However, due to the absence of specific information regarding the type of pelvic and acetabular fractures in the study population, these authors were unable to establish a causal relationship between the fractures themselves and fetal mortality. It is likely that the presence of either pelvic or acetabular fractures is a marker of the severity of the transfer of energy to the pregnant uterus and that the type and/or complexity of the fractures itself is less important from the standpoint of the risk of fetal mortality. One finding of interest in this study is that the presence of pelvic fractures is an independent risk factor for stillbirth regardless of gestational age. Similar conclusions were reported in a study by Cannada et al. [21] in which pelvic fractures and acetabular fractures were shown to be associated with a 30% rate of fetal death.

The severity of the injuries sustained during MVC depends not only on the characteristics of the accident itself, but also on the appropriate use of safety devices such as airbags and seat belts on the part of the pregnant woman. The frequency of use of seat belts by pregnant women was available in 8 of the 37 articles in which MVC was the reported mechanism of injury, which ranged from a low of 21% to high value of 98%. The type and the severity of maternal and fetal injury in MVC accidents are related to the appropriate use of seat belts and/or the presence of frontal and lateral airbags. Five of the six deaths reported in a series of 160 pregnant women involved in MVC were unrestrained women, two drivers, and three passengers [12]. There is a high correlation between the absence of use of seat belts and the revised trauma score (RTS) severity of injury suffered by pregnant women involved in MVC. Additional supportive evidence of the value of seat belt use by pregnant women in MVC is provided by Luley et al. [34]. These authors have shown that women who do not wear seat belts suffer more severe injuries; furthermore, they require more frequently non-obstetric surgery, primarily orthopedic procedures, as a result of the injuries sustained when compared to pregnant women wearing seat belts, 25% as opposed to 7%, respectively. While airbag deployment was more frequent in patients who had abruption placenta and fetal loss, there was no statistically significant correlation between the both. It is very likely that the abruption placenta and fetal loss are the result of the force of the impact and the transfer of the kinetic energy to the pregnant uterus from the MVC rather than the abdominal trauma caused by the deployed airbag. The absence of causal relationship between airbag deployment and placental abruption was investigated by Metz and his collaborators [2] in a retrospective study of 30 pregnant women (20 or more weeks' gestation) who were involved in a MVC with a reported median speed of 35 mph. Among the 30 women, one experienced PA with subsequent intrauterine fetal demise. This study suggests that PA occurs with a low frequency with airbag deployment. Based on computer modeling in crash tests dummies, airbag deployment may be a risk factor for PA and fetal loss in unbelted pregnant women, but it does not increase the risk of PA and fetal loss in properly restrained pregnant women [53].

Klinich et al. [16] investigated how restraint conditions and crash characteristics affected the fetal outcome in 57 pregnant women. Fetal loss occurred in 12 of 41 properly restrained occupants (29%), in contrast to three of the six (50%) improperly restrained women. Eight of the ten (80%) unrestrained women had adverse fetal outcomes. The rate of fetal death in unbelted women was 62%, while 79% of properly restrained women had only minor complications.

Table 2 Prevalence of the causes of trauma

Author (year)	MVC (%)	Fall (%)	Assault (%)	GSW (%)	SW (%)	Others (%)
Metz (2006) [2]	100	0	0	0	0	–
El Kady (2006) [3]	44	25	10	0	0	–
Barré (2006) [4]	51	41	0	0	0	8
Aniuliene (2006) [5]	NS	NS	NS	NS	NS	–
Weintraub (2006) [6]	NS	NS	NS	0	0	–
Sperry (2006) [7]	25	46	23	NR	NR	–
Hitosugi (2006) [8]	100	0	0	0	0	–
Kuo (2007) [9]	48	52	NS	1	NR	85
Aboutanos (2007) [10]	NS	NS	NS	NS	NS	–
Greene (2007) [11]	95	3	NR	NR	NR	–
Patteson (2007) [12]	85	6	2	1	NR	2
Kvarnstrand (2008) [13]	100	0	0	0	0	–
Weiss (2008) [14]	25	18	NS	0.1	NR	36
Cahill (2008) [15]	29	48	19	NR	NR	–
Klinich (2008) [16]	100	0	0	0	0	–
Aboutanos (2008) [17]	100	0	0	0	0	–
Schiff (2008) [18]	0	100	0	0	0	–
Nannini (2008) [19]	0	0	100	0	0	–
Dunning (2010) [20]	0	100	0	0	0	–
Cannada (2010) [21]	40	41	8	0	0	6
Tinker (2010) [22]	34	52	NR	NR	NR	15
Vladutiu (2010) [23]	0	64	0	0	0	–
Schiff (2010) [24]	100	0	0	0	0	–
Petrone (2011) [1]	NR	NR	11	73	23	–
Preeti (2011) [25]	NR	NR	NR	NR	NR	–
Vivian-Taylor (2012) [26]	100	0	0	0	0	–
Fischer (2011) [27]	20	20	9	NR	NR	–
Lin (2011) [28]	0	0	34	48	18	–
Meuleners (2011) [29]	0	0	100	NR	NR	–
Melamed (2012) [30]	39	50	3	0	0	–
Karadas (2012) [31]	21	56	NR	NR	NR	23
Mesdaghinia (2012) [32]	13	28	47	0	0	–
Njoku (2013) [33]	30	14	46	6	NR	–
Luley (2013) [34]	100	0	0	0	0	–
Vladutiu (2013) [35]	100	0	0	0	0	–
Periyanayagam (2014) [36]	75	NR	9	NR	NR	11
Brookfield (2013) [37]	72	4	4	10	9	–
Zangene (2014) [38]	47	26	25	NR	2	–
Wall (2014) [39]	26	7	52	10	7	–
Okeke (2014) [40]	0	100	0	0	0	–
Harland (2014) [41]	30	46	NR	NR	NR	–
Ibrahim (2015) [42]	0	0	100	0	0	–
Chibber (2015) [43]	100	0	0	0	0	–
Jackson (2015) [44]	0	0	100	0	0	–
Azar (2015) [45]	100	0	0	0	0	–
Van der Knoop (2015) [46]	50	44	6	0	0	–
Shakerian (2015) [47]	81	7	8	0	0	–
Weiner (2016) [48]	26	58	9	0	0	–
Miller (2016) [49]	100	0	0	0	0	–
Battaloglu (2016) [50]	56	32	11	NR	NR	–
Distelhorst (2016) [51]	33	32	5	NR	NR	–

NR not recorded, *NS* not specified, *MVC* motor vehicle collision, *GSW* gunshot wound, *SW* stab wound

Table 3 Maternal and fetal mortality

Author (year)	Maternal mortality (%)	Fetal mortality (%)
Metz (2006) [2]	NR	3
El Kady (2006) [3]	0.39	1
Barré (2006) [4]	NR	1
Aniuliene (2006) [5]	4	9
Hitosugi (2006) [8]	NR	55
Aboutanos (2007) [10]	0	4
Greene (2007) [11]	0	1
Patteson (2007) [12]	3	8
Kvarnstrand (2008) [13]	29	2
Weiss (2008) [14]	NR	1
Klinich (2008) [16]	NR	21
Aboutanos (2008) [17]	NR	5
Schiff (2008) [18]	NR	1
Schiff (2010) [24]	NR	0.4
Petrone (2011) [1]	9	83
Vivian-Taylor (2012) [26]	NR	31
Lin (2011) [28]	100	100
Meuleners (2011) [29]	NR	1
Melamed (2012) [30]	NR	1
Mesdaghinia (2012) [32]	0	1
Njoku (2013) [33]	2	8
Luley (2013) [34]	NR	4
Periyanayagam (2014) [36]	8	NR
Wall (2014) [39]	2	36
Chibber (2015) [43]	14	11
Shakerian (2015) [47]	NR	1
Miller (2016) [49]	NR	0.2
Distelhorst (2016) [51]	1	2

NR not recorded

Based on the results of their study, these authors conclude that women restrained by three-point seat belts are less likely to suffer severe injuries, with an 84% estimated reduction of the risk of fetal complications, potentially preventing an estimated 192 fetal losses.

Falls are the second most common cause of trauma during pregnancy, especially during the second and third trimester due primarily, amongst other reasons, to weight gain, and changes in the center of gravity. Most falls in pregnant women tend to be from a standing height. Schiff et al. [18] studied 693 women who fell during pregnancy, 79% of whom fell during the third trimester. The hospitalization rate was twice higher than in non-pregnant women, and resulted in a twofold increase in the risk of stillbirth. Although 54% of the patients had an ISS between one and eight, 90% required induction of labor, and 30% an emergency cesarean section. Okeke [40] has reported a 32.5% incidence of falls in a cross-sectional study of 332 pregnant women presenting in labor for delivery at the University of Nigeria Teaching Hospital Enugu, in Nigeria. This is similar to the 27% reported incidence of falls among pregnant women in the US [54].

Interpersonal violence during pregnancy poses also a high risk to both the mother and fetus. In the majority of cases, the injuries are limited to the soft tissues, head, neck, and torso sparing the abdomen. When the physical aggression is directed to the abdomen, there is an increased incidence of antepartum hemorrhage (AP) with subsequent perinatal complications. The reported prevalence of interpersonal violence ranges between 1 and 20% of all pregnant women, with the domestic partner identified as the aggressor in the majority of the cases [22]. However, the prevalence of interpersonal violence is affected by several factors, including socioeconomic factors, cultural upbringing, the status of women in the specific society, and the normative use of violence in conflict situations as it relates to different countries. Mesdaghinia et al. [32] have reported a 47% of incidence of domestic violence in Iran, especially during the second trimester of pregnancy. Ibrahim and others [42] have reviewed a series of 1857 Egyptian pregnant women to study the incidence of intimate partner abuse. In their study, 44% of pregnant women were found to have experienced some form of interpersonal violence, including physical violence (16%) and sexual assault (10%). According to the study of Meuleners et al. [29] that included 465 pregnant women exposed to interpersonal violence, injury associated with interpersonal violence resulted in a 1.7-fold risk in maternal

Table 4 AAST-OIS for gravid uterus [52]

Grade	Injury description
I	Hematoma or contusion without placental abruption
II	Superficial laceration < 1 cm in depth or placental abruption < 25%
III	Deep laceration 1 cm in depth in second trimester or placental abruption 25% but < 50%. Deep laceration in third trimester
IV	Laceration extending to the uterine artery. Deep laceration 1 cm with 50% placental abruption
V	Uterine rupture in second or third trimesters. Complete placental abruption

AAST-OIS American Association for the Surgery of Trauma Organ Injury Scale

complications (abortions, preterm, AP), and twofold risk in fetal adverse outcomes (low weight at birth, fetal distress, and fetal death). The risk of fetal death is directly correlated to the severity of maternal injuries. In the study by Njoku et al. [33] with a 50% reported incidence of domestic violence in pregnant women, 80% of fetal deaths occurred in women who had suffered severe maternal injuries, compared to a fetal loss rate of 20% in pregnant women with less severe injuries.

Pathophysiology

During pregnancy, there is a spatial redistribution of the viscera inside the abdominal cavity due to the progressive increase in the size of the uterus. The abdominal viscera are displaced cephalad as the uterus reaches the central region of the abdomen. That is the reason why penetrating abdominal injuries during the third trimester of pregnancy are associated not only with high maternal morbidity, but also with a significant increased incidence of uterine and fetal injury (60–70%), including a very high fetal death rate (40–65%). As reported by Shakerian et al. [47], the fetal death rate from stab and gunshot wounds is 42 and 71%, respectively. In a study by Petrone et al. [1], penetrating injuries, mostly gunshot wounds (73%) accounted for 9% of the mechanism of trauma in 321 pregnant women with abdominal trauma. The cohort of women suffering penetrating injuries had a significantly higher maternal morbidity (66 vs. 10%), as well as fetal mortality (73 vs. 10%) when compared to pregnant women who had blunt abdominal trauma.

The impact of abdominal trauma on the fetus depends to high degree on the gestational age at the time of the trauma. Direct injury to the uterus and fetus is unlikely during the first 12 weeks of gestation due to the protective effect of the bony pelvis, unless the traumatic event has caused complex pelvic fractures [55]. Miscarriage is uncommon following abdominal trauma during the first trimester unless the pregnant woman has suffered sustained hypotension leading to uterine hypoperfusion from extracavitary blood loss. Trauma during pregnancy can cause immediate fetal compromise; however, it can also be associated with delayed complications, such as delayed placenta abruption, which has been reported to occur up to 6 days after the traumatic event [56]. It is for this reason that prolonged fetal heart monitoring is required in pregnancies that have reached viability. Abdominal trauma may cause a subclinical chronic PA that may evolve into an acute episode of PA, preterm labor, premature membrane rupture, and placental insufficiency that may, in turn, cause fetal growth retardation, oligohydramnios, and low birth weight. The short- and long-term complications of blunt trauma during pregnancy were investigated by Melamed et al. [30] in a retrospective cohort study of 411 pregnant women. Thirteen women who had immediate complications were compared to 398 women who did not suffer any complications. In addition, 303 pregnant women who did not deliver at the time of the traumatic event were compared to a normal cohort of 909 matched by maternal age and parity to assess the impact of trauma on the outcome of the pregnancy. Immediate complications in the form of preterm labor and AP occurred in 3.2% of women. Independent risk factors for immediate complications included high severity of trauma, multiple gestations, vaginal bleeding, and the development of uterine contractions. Late-term complications, including preterm labor, PA, and perinatal morbidity, were also associated with a high ISS and the requirement for laparotomy at the time of the trauma.

Primary treatment

After the 10th week of pregnancy, there is an increase in plasma volume by up to 50% with a dilutional anemia secondary to a lesser increase in the red blood cell mass (15–30%) relative to the expansion of the plasma volume. These changes can provide some maternal tolerance to hemorrhagic shock. Therefore, symptoms such as tachycardia or hypotension may not occur until there is a blood loss, as high as 35% [57]. Blood pressure less than 80/40 mmHg, a pulse greater than 140 or less than 50 beats per minute, a respiratory rate less than 10 or greater than 24, and a fetal heart rate less than 110 or greater than 160 beats per minute are associated with the presence of shock. If used, the abdominal portion of the military anti-shock trousers (MAST) should be deflated en route, since compression can reduce blood flow to the placenta [57, 58]. The presence of any of the above reflects the severity of trauma and should alert the trauma surgeon to a high risk of maternal and fetal morbidity and mortality. In addition, during the second and third trimesters of pregnancy, the compression of the inferior vena cava in the supine position by the gravid uterus can contribute to a state of hypotension because of the decreased venous return. To avoid this, the patient must be placed in the 15°–30° left tilt position by placing a firm wedge underneath the right buttock/hip, manually displacing the uterus if necessary, always ensuring the immobilization of the cervical spine [57, 59].

The use of vasopressors, such as norepinephrine or phenylephrine, is not recommended, since they reduce placental perfusion, unless the patient does not respond to appropriate volume loading with crystalloids. Both the mother and the fetus are extremely vulnerable to hypoxia due to the respiratory changes associated with pregnancy, namely, a shallow breathing pattern, decreased functional residual capacity, and the increased oxygen consumption by 20%; therefore, the administration of supplemental oxygen is always required. The elevation of the diaphragm up to 4 cm compared to its normal anatomical position must be taken

into account when undertaking any thoracic procedure such as the performance of tube thoracostomy [56]. If necessary, the chest tube should be placed one or two intercostal spaces above the fifth intercostal space to avoid abdominal injuries. Due to the increased uterine size, there is a displacement of the lower esophageal sphincter that reduces its competence. In addition, the physiological inhibition of gastric motility and the increased relaxation of the lower esophageal sphincter predispose the pregnant woman to the risk of aspiration. To avoid aspiration, placement of a decompressive nasogastric tube is warranted [57, 59].

Definitive treatment

After the initial assessment is performed (Fig. 1) [60], and once maternal hemodynamic stability is reached, fetal monitoring should be initiated immediately. Information about the obstetric history such as gestational age, fetal maturity, date of delivery, and any other complication during pregnancy

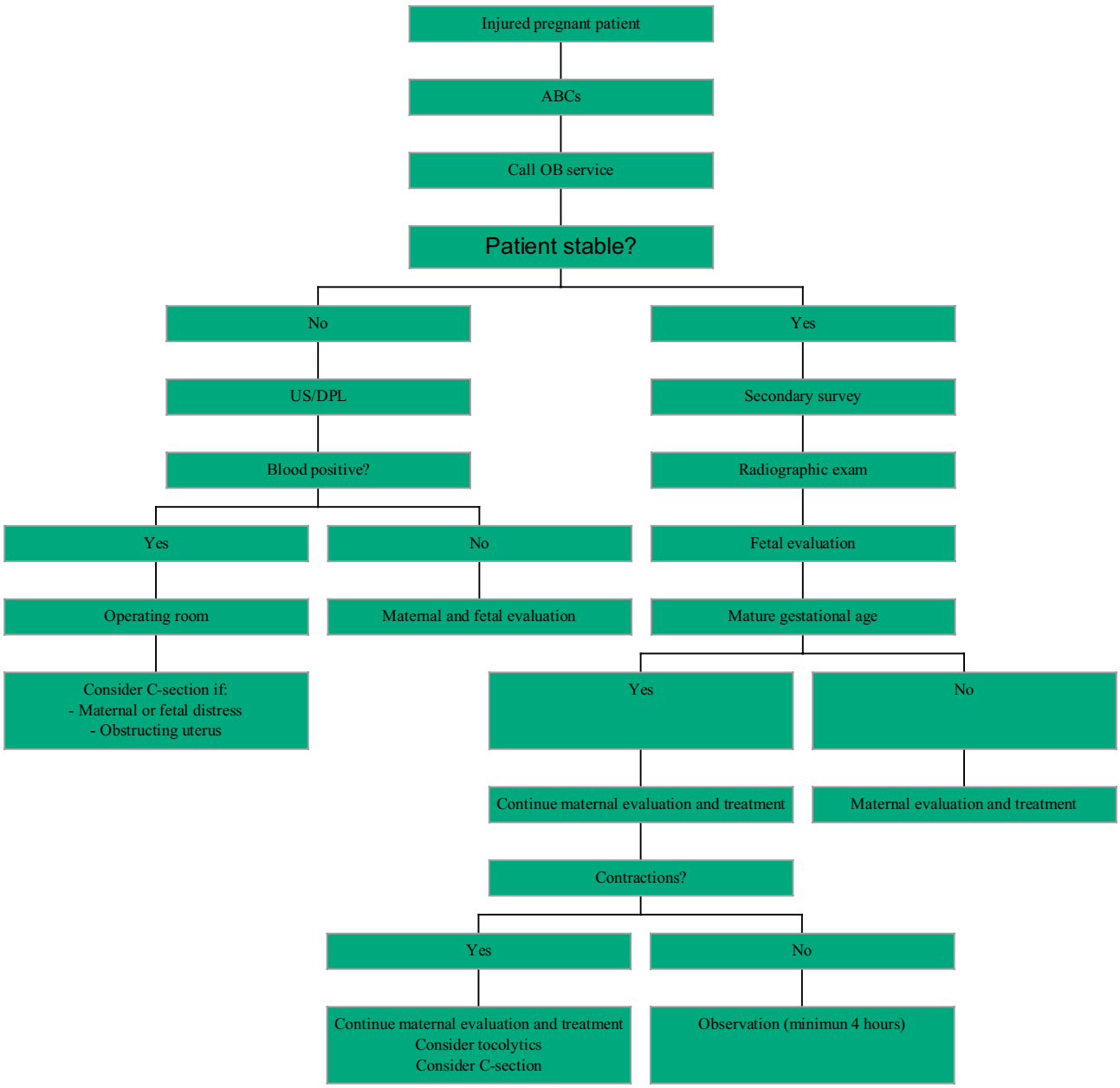

Fig. 1 Algorithm for initial maternal and fetal assessment [60]. *OB* Obstetrics, *US* ultrasound, *DPL* diagnostic peritoneal lavage, *C-section* cesarean section. Modified from Petrone P, Tillou A. Gynecologic injuries: trauma to gravid and nongravid uterus and female genitalia. In: Current therapy of trauma and surgical critical care. (Elsevier, Philadelphia, 2016), pp 401–407

must be obtained [59]. During the physical examination, particular attention should be paid to signs of trauma such as vaginal bleeding, spontaneous rupture of membranes, presence, intensity and frequency of uterine contractions, and abnormal fetal heart rate [58]. The possibility of bleeding and fetal-placental transfusion must be evaluated using the Kleihauer–Betke test, with appropriate administration of AntiD immunoglobulin in Rh negative mothers. A multidisciplinary assessment that includes evaluation by the obstetrician is recommended [60].

Imaging during pregnancy and the negative impact that radiation may have on fetal development remain controversial. However, if these tests are clinically justified, the indications for imaging are the same as for any other non-pregnant trauma patient, and do not have to be delayed as the benefits outweigh the risks. Fetal harm due to radiation depends on the gestational age of exposure, with the most vulnerable time being within the first 16 weeks of gestation [57]. Computed tomography (CT) scans can identify maternal and fetal injuries, but should be only performed when the patient is hemodynamically stable. Despite the high sensitivity and specificity of CT, focused abdominal sonography for trauma (FAST) is considered the gold standard due to its safety and a non-invasive nature. FAST can identify solid organs injuries, the presence of free fluid, fetal well-being, gestational age, amniotic fluid volume, and location of the placenta. Other diagnostic techniques, such as diagnostic peritoneal lavage (DPL) can be safely done, if performed above the umbilicus.

Maternal pelvic fractures are the most common cause of fetal death amongst traumatic injuries. When taken in isolation, pelvic fractures do not represent an indication for emergency cesarean section, since vaginal delivery can be performed safely, even in the third trimester of pregnancy in most cases [3, 21, 59]. Angioembolization is the ideal treatment for pelvic or retroperitoneal hemorrhage, although the radiation dose is considered excessive and it is not exempted of fetal complications [57].

When the fetus is viable (more than 24 weeks' gestation) continued fetal monitoring must be provided. A minimum of 2–6 h and up to 48 h of monitoring is recommended, as some cases of placental abruption have been reported more than 24 h after the initial injury. Fetal arrhythmia may be the first sign of maternal hemodynamic compromise. As placental perfusion and oxygenation depend directly on maternal cardiorespiratory condition, continuous fetal monitoring is recommended in cases of maternal acute respiratory distress syndrome, severe lung damage, or abnormal heart rhythm. In low-risk patients with minor trauma and once any maternal injury are excluded, fetal monitoring for 4 h appears to be a sufficient period of monitoring.

Perimortem cesarean section in viable fetuses can be successful if performed no later than 4 min following maternal cardiac arrest. Fetal survival rates are excellent with a reported fetal survival rate of 70%. A vertical uterine midline section is recommended to avoid injury to the uterine vessels. The recommendations [60, 61] for emergency cesarean section are listed in Table 5.

Table 5 Indications for emergency cesarean section [60, 61]

Viable pregnancies (> 24 weeks) or near term
Maternal death
Trauma patients with cardiac arrest
No later than 4 min of properly performed cardiopulmonary resuscitation that has failed
Loss of fetal well-being in viable fetus
Irreparable uterine rupture
Massive hemorrhage/shock
Threat to life from exsanguination from any cause
Mechanical limitation for maternal repair
Unstable thoracolumbar spine injury

Conclusion

Trauma in pregnant women represents a significant public health burden and a clinical challenge for the trauma surgeon given the complexity of the pregnant woman. The priority should always lie with the mother. While injuries to the gravid uterus are uncommon, they should be suspected in all assault victims and all patients with direct perineal trauma, pelvic fractures, or penetrating injury to the pelvis. An obstetrician is an essential member of the multidisciplinary team for the initial assessment, stabilization, and subsequent management of a pregnant trauma victim. Pregnant women must be educated on the proper use of restraints, and screening for domestic abuse and depression are essential components of quality care of this unique population. It is of a great importance that all professionals specializing in treating trauma patients recognize and are aware of the anatomic and physiologic changes that occur to pregnant women and how these changes can impact the evaluation and treatment of this unique patient population.

Compliance with ethical standards

Conflict of interest Patrizio Petrone, Patricia Jiménez Morillas, Alexander Axelrad, and Corrado P. Marini declare that they have not conflict of interest.

Informed consent This research consisted of literature review only, and, therefore, did not involve human participants or animals.

References

1. Petrone P, Talving P, Browder T, Teixeira PG, Fisher O, Lozornio A, Chan LS. Abdominal injuries in pregnancy: a 155-month study at two level 1 trauma centers. Injury. 2011;42(1):47–9.
2. Metz TD, Abbott JT. Uterine trauma in pregnancy after motor vehicle crashes with airbag deployment: a 30-case series. J Trauma. 2006;61(3):658–61.
3. El Kady D, Gilbert WM, Xing G, Smith LH. Association of maternal fractures with adverse perinatal outcomes. Am J Obstet Gynecol. 2006;195(3):711–6.
4. Barré M, Winer N, Caroit Y, Boog G, Philippe HJ. Abdominal trauma during pregnancy: pertinence of monitoring elements. J Gynecol Obstet Biol Reprod. 2006;35(7):673–7.
5. Aniuliene R, Proseviciūte L, Aniulis P, Pamerneckas A. Trauma in pregnancy: complications, outcomes, and treatment. Medicina (B Aires). 2006;42(7):586–91.
6. Weintraub AY, Levy A, Holcberg G, Sheiner E. The outcome of blunt abdominal trauma preceding birth. Int J Fertil Womens Med. 2006;51(6):275–9.
7. Sperry JL, Casey BM, McIntire DD, Minei JP, Gentilello LM, Shafi S. Long-term fetal outcomes in pregnant trauma patients. Am J Surg. 2006;192(6):715–21.
8. Hitosugi M, Motozawa Y, Kido M, Yokoyama T, Kawato H, Kuroda K, Tokudome S. Traffic injuries of the pregnant women and fetal or neonatal outcomes. Forensic Sci Int. 2006;159(1):51–4.
9. Kuo C, Jamieson DJ, McPheeters ML, Meikle SF, Posner SF. Injury hospitalizations of pregnant women in the United States, 2002. Am J Obstet Gynecol. 2007;196(2):161.e1–6. **(Erratum in: Am J Obstet Gynecol 2007;196(6):614–5)**.
10. Aboutanos SZ, Aboutanos MB, Dompkowski D, Duane TM, Malhotra AK, Ivatury RR. Predictors of fetal outcome in pregnant trauma patients: a five-year institutional review. Am Surg. 2007;73(8):824–7.
11. Greene W, Robinson L, Rizzo AG, Sakran J, Hendershot K, Moore A, et al. Pregnancy is not a sufficient indicator for trauma team activation. J Trauma. 2007;63(3):55 – 5.
12. Patteson SK, Snider CC, Meyer DS, Enderson BL, Armstrong JE, Whitaker GL, Carroll RC. The consequences of high-risk behaviors: trauma during pregnancy. J Trauma. 2007;62(4):1015–20.
13. Kvarnstrand L, Milsom I, Lekander T, Druid H, Jacobsson B. Maternal fatalities, fetal and neonatal deaths related to motor vehicle crashes during pregnancy: a national population-based study. Acta Obstet Gynecol Scand. 2008;87(9):946–52.
14. Weiss HB, Sauber-Schatz EK, Cook LJ. The epidemiology of pregnancy-associated emergency department injury visits and their impact on birth outcomes. Accid Anal Prev. 2008;40(3):1088–95.
15. Cahill AG, Bastek JA, Stamilio DM, Odibo AO, Stevens E, Macones GA. Minor trauma in pregnancy–is the evaluation unwarranted? Am J Obstet Gynecol. 2008;198(2):208.e1–5.
16. Klinich KD, Flannagan CA, Rupp JD, Sochor M, Schneider LW, Pearlman MD. Fetal outcome in motor-vehicle crashes: effects of crash characteristics and maternal restraint. Am J Obstet Gynecol. 2008;198(4):450–9.
17. Aboutanos MB, Aboutanos SZ, Dompkowski D, Duane TM, Malhotra AK, Ivatury RR. Significance of motor vehicle crashes and pelvic injury on fetal mortality: a five-year institutional review. J Trauma. 2008;65(3):616 – 20.
18. Schiff MA. Pregnancy outcomes following hospitalization for a fall in Washington State from 1987 to 2004. BJOG. 2008;115(13):1648–54.
19. Nannini A, Lazar J, Berg C, Barger M, Tomashek K, Cabral H, et al. Physical injuries reported on hospital visits for assault during the pregnancy-associated period. Nurs Res. 2008;57(3):144–9.
20. Dunning K, Lemasters G, Bhattacharya A. A major public health issue: the high incidence of falls during pregnancy. Matern Child Health J. 2010;14(5):720–5.
21. Cannada LK, Pan P, Casey BM, McIntire DD, Shafi S, Leveno KJ. Pregnancy outcomes after orthopedic trauma. J Trauma. 2010;69(3):694–8.
22. Tinker SC, Reefhuis J, Dellinger AM, Jamieson DJ. National birth defects prevention study. Epidemiology of maternal injuries during pregnancy in a population-based study, 1997–2005. J Womens Health (Larchmt) 2010;19(12):2211–8.
23. Vladutiu CJ, Evenson KR, Marshall SW. Physical activity and injuries during pregnancy. J Phys Act Health. 2010;7(6):761–9.
24. Schiff MA, Mack CD, Kaufman RP, Holt VL, Grossman DC. The effect of air bags on pregnancy outcomes in Washington State: 2002–2005. Obstet Gynecol. 2010;115(1):85–92.
25. Preeti R, hiozawa A, Haut ER, Efron DT, Haider A, Cornwell EE 3rd, Chang D. An assessment of the impact of pregnancy on trauma mortality. Surgery. 2011;149(1):94–8.
26. Vivian-Taylor J, Roberts CL, Chen JS, Ford JB. Motor vehicle accidents during pregnancy: a population-based study. BJOG. 2012;119(4):499–503.
27. Fischer PE, Zarzaur BL, Fabian TC, Magnotti LJ, Croce MA. Minor trauma is an unrecognized contributor to poor fetal outcomes: a population-based study of 78,552 pregnancies. J Trauma. 2011;71(1):90–3.
28. Lin P, Gill JR. Homicides of pregnant women. Am J Forensic Med Pathol. 2011;32(2):161–3.
29. Meuleners LB, Lee AH, Janssen PA, Fraser ML. Maternal and foetal outcomes among pregnant women hospitalised due to interpersonal violence: a population based study in Western Australia, 2002–2008. BMC Pregnancy Childbirth. 2011–2012;11:70.
30. Melamed N, Aviram A, Silver M, Peled Y, Wiznitzer A, Glezerman M, Yogev Y. Pregnancy course and outcome following blunt trauma. J Matern Fetal Neonatal Med. 2012;25(9):1612–7.
31. Karadaş S, Gönüllü H, Oncü MR, Kurdoğlu Z, Canbaz Y. Pregnancy and trauma: analysis of 139 cases. J Turk Ger Gynecol Assoc. 2012;13(2):118–22.
32. Mesdaghinia E, Sooky Z, Mesdaghinia A. Causes of trauma in pregnant women referred to Shabih-Khani maternity hospital in Kashan. Arch Trauma Res. 2012;1(1):23–6.
33. Njoku OI, Joannes UO, Christian MC, Azubike OK. Trauma during pregnancy in a Nigerian setting: patterns of presentation and pregnancy outcome. Int J Crit Illn Inj Sci. 2013;3(4):269–73.
34. Luley T, Fitzpatrick CB, Grotegut CA, Hocker MB, Myers ER, Brown HL. Perinatal implications of motor vehicle accident trauma during pregnancy: identifying populations at risk. Am J Obstet Gynecol. 2013;208(6):466.
35. Vladutiu CJ, Marshall SW, Poole C, Casteel C, Menard MK, Weiss HB. Adverse pregnancy outcomes following motor vehicle crashes. Am J Prev Med. 2013;45(5):629–36.
36. Periyanayagam U, Crandall M. The cost of injury: hospital charges for pregnant trauma patients, 1999 to 2003. Am J Surg. 2014;208(1):130–5.
37. Brookfield KF, Gonzalez-Quintero VH, Davis JS, Schulman CI. Maternal death in the emergency department from trauma. Arch Gynecol Obstet. 2013;288(3):507–12.
38. Zangene M, Ebrahimi B, Najafi F. Trauma in pregnancy and its consequences in Kermanshah, Iran from 2007 to 2010. Glob J Health Sci. 2014;7(2):304–9.
39. Wall SL, Figueiredo F, Laing GL, Clarke DL. The spectrum and outcome of pregnant trauma patients in a metropolitan trauma service in South Africa. Injury. 2014;45(8):1220–3.

40. Okeke TC, Ugwu EO, Ikeako LC, Adiri CO, Ezenyeaku CC, Ekwuazi KE, Okoro OS. Falls among pregnant women in Enugu, Southeast Nigeria. Niger J Clin Pract. 2014;17(3):292–5.
41. Harland KK, Saftlas AF, Yankowitz J, Peek-Asa C. Risk factors for maternal injuries in a population-based sample of pregnant women. J Womens Health. 2014;23(12):1033–8.
42. Ibrahim ZM, Sayed Ahmed WA, El-Hamid SA, Hagras AM. Intimate partner violence among Egyptian pregnant women: incidence, risk factors, and adverse maternal and fetal outcomes. Clin Exp Obstet Gynecol. 2015;42(2):212–9.
43. Chibber R, Al-Harmi J, Fouda M, El-Saleh E. Motor-vehicle injury in pregnancy and subsequent feto-maternal outcomes: of grave concern. J Matern Fetal Neonatal Med. 2015;28(4):399–402.
44. Jackson CL, Ciciolla L, Crnic KA, Luecken LJ, Gonzales NA, Coonrod DV. Intimate partner violence before and during pregnancy: related demographic and psychosocial factors and postpartum depressive symptoms among Mexican American women. J Interpers Violence. 2015;30(4):659–79.
45. Azar T, Longo C, Oddy L, Abenhaim HA. Motor vehicle collision-related accidents in pregnancy. J Obstet Gynaecol Res. 2015;41(9):1370–6.
46. Van der Knoop BJ, van Schie PE, Vermeulen RJ, Pistorius LR, van Weissenbruch MM, de Vries JI. Effect of (minor or major) maternal trauma on fetal motility: a prospective study. Early Hum Dev. 2015;91(9):511–7.
47. Shakerian R, Thomson BN, Judson R, Skandarajah AR. Radiation fear: impact on compliance with trauma imaging guidelines in the pregnant patient. J Trauma Acute Care Surg. 2015;78(1):88–93.
48. Weiner E, Gluck O, Levy M, Ram M, Divon M, Bar J, Kovo M. Obstetric and neonatal outcome following minor trauma in pregnancy. Is hospitalization warranted? Eur J Obstet Gynecol Reprod Biol. 2016;203:78–81.
49. Miller N, Biron-Shental T, Peleg K, Fishman A, Olsha O, Givon A, Kessel B. Are pregnant women safer in motor vehicle accidents? J Perinat Med. 2016;44(3):329–32.
50. Battaloglu E, McDonnell D, Chu J, Lecky F, Porter K. Epidemiology and outcomes of pregnancy and obstetric complications in trauma in the United Kingdom. Injury. 2016;47(1):184–7.
51. Distelhorst JT, Krishnamoorthy V, Schiff MA. Association between hospital trauma designation and maternal and neonatal outcomes after injury among pregnant women in Washington State. J Am Coll Surg. 2016;222(3):296–302.
52. Moore EE, Jurkovich GJ, Knudson MM, Cogbill TH, Malangoni MA, Champion HR, Shackford SR. Organ injury scaling VI: extrahepatic biliary, esophagus, stomach, vulva, vagina, uterus (non-pregnant), uterus (pregnant), fallopian tube, and ovary. J Trauma. 1995;39:1069–70.
53. Pearlman MD, Viano D. Automobile crash simulation with the first pregnant crash test dummy. Am J Obstet Gynecol. 1996;175:977–81.
54. Dunning K, Lemasters G, Bhattacharya A. A major public health issue: The high incidence of falls during pregnancy. Matern Child Health J. 2010;14:720-5.
55. American College of Obstetricians and Gynecologists. ACOG educational bulletin. Obstetric aspects of trauma management. Int J Gynaecol Obstet 1999;64:87–94.
56. Higgins SD, Garite TJ. Late abruptio placenta in trauma patients: implications for monitoring. Obstet Gynecol. 1984;63(3Suppl):10S-12S.
57. Petrone P, Marini CP. Trauma in pregnant patients. Curr Probl Surg. 2015;52(8):330 – 51.
58. Mendez-Figueroa H, Dahlke JD, Vrees RA, Rouse DJ. Trauma in pregnancy: an updated systematic review. Am J Obstet Gynecol. 2013;209(1):1–10.
59. Petrone P, Asensio JA. Trauma in pregnancy: assessment and treatment. Scand J Surg. 2006;95(1):4–10.
60. Petrone P, Tillou A. Gynecologic injuries: trauma to gravid and nongravid uterus and female genitalia. In: Asensio JA, Trunkey D, editors. Current therapy of trauma and surgical critical care. Philadelphia: Elsevier; 2016. pp. 401–7. Second Edition.
61. Jain V, Chari R, Maslovitz S, Farine D;, Bujold E, et al. Maternal Fetal Medicine Committee. Guidelines for the management of a pregnant trauma patient. J Obstet Gynaecol Can. 2015;37(6):553–74.