Management and Outcomes of Trauma During Pregnancy

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KEYWORDS

• Pregnancy • Wounds and injuries • Multiple trauma • Anesthesia and analgesia • Therapeutics • Education • Outcome and process assessment (health care) • Pregnancy outcome

KEY POINTS

- Approximately 1% to 4% of pregnant women are evaluated in emergency/delivery rooms because of traumatic injury.
- Pregnancy should be sought in all trauma cases involving women of childbearing age.
- Use of illicit drugs and alcohol, domestic abuse, and depression contribute to maternal trauma; thus a high index of suspicion should be maintained when treating injured young women.
- If pregnancy is confirmed, gestational age should be assessed while providers adhere to the advanced trauma life support (ATLS) guidelines.
- Fetal viability should be assessed after maternal stabilization.
- Pregnancy-related morbidity occurs in approximately 25% of cases and may include placental abruption, uterine rupture, preterm delivery, and the need for cesarean delivery (CD).

EPIDEMIOLOGY

The rate of maternal death due to penetrating trauma, suicide, homicide, and motor vehicle accidents (MVAs) is increasing,[1] whereas the rate of maternal death from direct causes is decreasing. This seemingly increased mortality may be the result of

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improved ascertainment of death during pregnancy.[2] Population-based studies show that approximately 1% to 4% of pregnant women are admitted for medical treatment because of traumatic injury,[3–5] the predominant cause of external injury during pregnancy being falls.[3,4] Although MVAs, domestic and/or nondomestic violence, and self-inflicted injury are less common than falls, they are associated with a higher likelihood of severe injury and death[3] and are perceived to be within societal responsibility.[6–9]

Pregnancy-related death is defined as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death. Contrary to maternal death, accidental or incidental causes are included in the definition of pregnancy-related death. The definition of pregnancy-related death was introduced at the time of change from ICD9 to ICD10 coding and facilitated the identification of maternal deaths not directly associated with the pregnant state, in circumstances in which the cause of death was incidental.[10] Before this change, no code existed for incidental cause of death during pregnancy. Hence the cause of death was frequently misclassified as pregnancy related. Many trauma databases still lack fields for data regarding pregnancy. Because registry data on maternal trauma remains deficient, most publications constitute retrospective analyses of causes of maternal deaths in single institutions rather than prospective analyses of maternal injury across multiple medical centers.

The case fatality rate of MVAs during pregnancy remains relatively low compared with the case fatality rates from causes such as maternal cardiovascular diseases[11] and thromboembolic phenomena during pregnancy.[12,13] However, because the average person has a 1:200 lifetime risk for being involved in a fatal MVA and a 57% lifetime risk of being injured in an MVA,[14] it is not surprising that MVAs constitute a significant cause of maternal, fetal, and neonatal death in North America and Europe. Worldwide, data from the Global Burden of Disease study of mortality among adolescents and young adults (ages 10–24 years) showed that within the category of deaths from injury, MVAs constituted the most significant cause of death and accounted for 5% of female deaths among women of childbearing age regardless of the existence of a pregnancy at the time of trauma.[15]

Several variables have been associated with maternal injury and death from trauma. Data from the American College of Surgeons National Trauma Data Bank associate 19.6% of pregnancy-related traumas with the use of illicit drugs and 12.9% of pregnancy-related traumas with the use of alcohol.[16] Poor compliance with the use of restraints during pregnancy is not a major issue. Use of restraints is generally similar to that of the general MVA population in the United States,[17] although it is highly dependent on the region.[16,18,19] Intimate partner abuse is an important contributor to maternal trauma.[20] Unwanted pregnancy may play a substantive role in this type of violence,[21] and pregnancy during adolescence is associated with a higher-than-usual likelihood of both violence and suicide.[22–24] Because homicide and suicide-related maternal deaths are often underreported[25,26] and both could be associated with MVA injury, one should bear in mind that nonfatal violence and suicide attempts may also be associated with pregnancy and a high index of suspicion should be maintained when treating young women thus injured.[27]

THE PRIMARY AND SECONDARY SURVEYS AND SURGICAL TREATMENT

The ATLS guidelines provide a framework for rapid assessment and management of the injured patient and have been demonstrated to improve patient outcomes.[28,29] Implementation of the ATLS guidelines deflects needless deaths during the first stage of resuscitation.[30] Although a multidisciplinary team approach is recommended for the

treatment of pregnant trauma patients,[28,31] all providers caring for such patients should follow the ATLS guidelines.[28]

All women of childbearing age should be assessed for possible pregnancy. If pregnancy is confirmed, estimation of the gestational age has implications for fetal viability and adds to the complexity of the decision-making process. Gestational age may be assessed either through patient history or by physical examination of the pelvis and abdomen; the uterine fundus is palpable above the pubic crest from the second trimester of gestation.

The ATLS guidelines should be adhered to despite the distracting presence of the fetus.[32] Treating the mother appropriately is beneficial for both the mother and the fetus.[31] The modifications to ATLS guidelines that may be considered for the pregnant casualty are provision of supplemental oxygen (because of maternal susceptibility to hypoxia and desaturation, see "Section on anesthetic management"),[33] preference for establishment of intravenous access above the diaphragm,[34] and left lateral positioning of the patient as soon as possible[35] (because of the possibility of reduced venous return secondary to uterine pressure on the vena-cava [aortocaval syndrome]).

Notwithstanding the presence of a pregnancy, the secondary survey should include the usual in-depth physical assessment of injuries. In addition, an obstetrician should conduct a proper pelvic examination to ascertain fetal position and should perform an examination for cervical dilation/effacement and the presence of blood and/or amniotic fluid leakage.[28] Placenta previa must be excluded before sterile vaginal examination of a pregnant patient with vaginal bleeding because bleeding may be provoked/exacerbated by the examination.[36] Previous publications examining the quality of maternal care after an MVA suggest that the presence of a pregnancy may distract the trauma team's attention away from the mother.[32,37] Because both maternal and fetal survival are primarily dependent on maternal well-being, assessment of fetal viability should be withheld until both the primary and secondary surveys of the mother have been performed and a formal pelvic examination has been performed in full.

In cases of massive transfusion, general trauma protocols should be adhered to; obstetric transfusion guidelines have recently adopted the transfusion protocols used in trauma.[38] Blood testing should also be in accordance with the regular trauma protocol[28,31] with the addition of a Kleihauer–Betke (KB) test (see "Section on Obstetric workup and treatment"). Radiographic examinations and computed tomography should be performed according to routine indications (see "Diagnostic Imaging").[39,40] The accuracy of focused abdominal sonography for trauma during pregnancy is almost comparable to that observed in nonpregnant women.[41–44] The indications for surgery are similar in pregnant and nonpregnant patients, and urgent maternal surgery should not be delayed for the purpose of assessing fetal viability. It is prudent to add an obstetrician to the surgical team in cases requiring abdominal/pelvic surgery.

OBSTETRIC WORKUP AND TREATMENT

Maternal Assessment

Clinical examination during the secondary survey constitutes the first step in assessing the risk for obstetric complications such as placental abruption, uterine rupture, preterm delivery, and need for CD. Further workup includes monitoring of the fetal heart rate (FHR) and uterine activity, ultrasonographic evaluation of the fetus and the pregnancy, further imaging modalities, and laboratory studies. Obstetric ultrasonography should be used to ascertain the gestational age, confirm the presence of a FHR, identify multifetal pregnancy, and seek placental abruption.[45] The clinician

should, however, keep in mind the low sensitivity of ultrasound testing for this indication; thus a negative result for placental abruption does not exclude this possibility.[46,47] Placental abruption complicates 1.7% of maternal traumas and is significantly more common after blunt trauma (4.4%–6.8%).[48–50] Although placental abruption is more likely with increasing severity of maternal injury, it may occur and thus should be considered, even with mild trauma.[49] Signs and symptoms include abdominal pain, contractions with pain that is disproportionate to the degree of cervical dilation, and/or vaginal bleeding. Physical examination reveals a tender and rigid uterus. Hemorrhage may be occult even when significant and may lead to coagulopathy and hemodynamic instability. Appropriate therapies consist of correction of hematological abnormalities in mild cases and prompt delivery in severe cases.

Uterine rupture is often associated with other severe injuries. Maternal death may be caused by massive hemorrhage from the ruptured uterus or from the associated injuries, and fetal/neonatal death occurs in up to 17.5% of the cases.[13]

Amniotic fluid embolus is a rare event specifically after trauma.[51] The presenting signs and symptoms may vary, including respiratory distress, shock or severe hypertension, coma, seizure, disseminated intravascular coagulation, cardiac arrest, or other coagulation disorders. All these presentations contribute to the high reported maternal mortality of 30% to 50%. Thus these clinical situations, which may be associated with amniotic fluid embolism, warrant prompt recognition and appropriate supportive care, to optimize outcomes.[52]

Fetal assessment should be performed only after maternal stability has been established.[31] Uterine activity should be monitored when the gestational age is greater than 20 weeks, and FHR should be monitored when the gestational age is greater than 24 weeks.[28,31] Recurrent uterine contractions suggest premature labor if accompanied by cervical change.[28] Excess uterine activity (>4 contractions per hour) suggests either placental abruption, which may jeopardize both maternal and fetal life, or preterm contractions, which too may lead to premature labor.

Early recognition of fetal distress may improve fetal outcome. The optimal length of continuous FHR monitoring is not well established, but most authorities concur on an initial 2 to 6 hours.[31] Monitoring for at least 24 hours may be indicated for both obstetric and trauma-associated reasons (**Box 1**).[28,31] Abnormal FHR observed during

Box 1
Indications for prolonged obstetric monitoring (ie, beyond the initial period of 2–6 hours)

Obstetric findings[a]
Suspected placental abruption
Suspected preterm labor
Evidence of uterine contractions
Evidence of vaginal bleeding
Any sign of fetal distress
Trauma-associated findings
Maternal injuries requiring admission in accordance with trauma guidelines (unrelated to pregnancy)
Requires general anesthesia
Severe head injury

[a] Observed within the initial 2- to 6-hour monitoring period.

continuous monitoring best recognizes fetal distress[53] but may also be the first sign of maternal hemodynamic compromise because of blood shunting from the uterus.[54,55] If a nonreassuring FHR pattern is detected, with no evidence of maternal compromise, "in utero resuscitation" should be attempted (ie, provision of supplemental oxygen and fluids to the mother and left lateral decubitus positioning).[56] Lack of improvement should lead to expedited delivery, most likely through CD.

Fetal–maternal hemorrhage may complicate 10% to 30% of maternal traumas.[57] The KB test detects fetal blood cells in the maternal circulation, and in Rh-negative mothers, this test can provide a rough estimate of the volume of maternal–fetal hemorrhage. Rh-negative pregnant patients should receive Rh-D immunoglobulin within 72 hours of injury to prevent future Rh alloimmunization.

DIAGNOSTIC IMAGING

Plain radiographs of the cervical spine, chest, and pelvis are the recommended ATLS adjuncts to the primary survey. The trauma team should be acquainted through institution-specific drills with local guidelines regarding management of maternal trauma. A priori training will enable diagnostic imaging to be performed without delay despite diagnosis of a pregnancy at the critical time that the medical team is attempting to save the life of the trauma patient.[58] Without advance training, delays may transpire as physicians ponder the balance between maternal benefit and potential fetal harm. This situation is complicated further by the fact that diagnostic guidelines are not always evidence based.

Two variables determine the type and severity of damage caused during fetal exposure to radiation: the gestational age (ie, the developmental stage of the fetus) and the radiation dose. At a gestational age of 4 to 10 weeks (ie, the period of organogenesis), radiation is most likely to cause congenital malformations. The fetus is most susceptible to radiation-induced mental retardation at a gestational age of 10 and 17 weeks,[59] but there have been reports of developmental injury with fetal exposure up to 25 weeks.[60] The risk of noncancer biologic injury caused by exposure to diagnostic imaging levels of radiation diminishes with increasing gestational age and reaches a minimum by a gestational age greater than 26 weeks.[59] In contrast, childhood leukemia has been associated with fetal exposure to radiation at any stage.[59]

Although natural ionized radiation is a constant daily occurrence, the American College of Radiologists Practice Guidelines recommend that diagnostic imaging for pregnant patients be minimized if possible.[61] A radiation dose less than 50 mSv is not likely to increase the risk of fetal malformation or childhood cancer. Medical diagnostic imaging techniques use less than this dose, even when pelvic or whole body computed tomography is performed (these imaging procedures entail the highest exposure).[62,63] The dose of radiation associated with neonatal death or miscarriage (even during late pregnancy) is far higher than that used in diagnostic radiology (>1 Gy). Nonetheless, the possibility that in utero exposure to radiation may be associated with an increased risk of childhood leukemia (absolute risk ~1:2000) should guide physicians to maintain exposure to the lowest possible level.[39,64] Several possibilities exist for reducing the radiation dose in emergency trauma cases complicated by pregnancy; Use of a posteroanterior exposure method can increase the distance from the anterior uterus.[59] Computed tomography can be performed with increased slice depth, reduced current, or increased pitch. Internal shielding[65] and lead apron shielding[62] have been advocated where possible.[61]

Abortion is not recommended in cases of fetal exposure to diagnostic radiation[66] because it is unlikely that the dose administered during a diagnostic procedure will

harm the fetus.[67,68] After maternal trauma issues have been resolved, the parents should be informed regarding fetal exposure to radiation. This information should be accompanied by suitable explanation of the inclusive nature of reports of childhood cancer after in utero exposure to radiation.

Contrast media, lipid-soluble solutions, and small-molecular-weight solutions easily penetrate the placental barrier[69] and are potentially teratogenic.[63] Use of radioiodine isotopes is contraindicated during pregnancy because of concerns regarding the likelihood of inducing thyroid cancer in the fetus.[66] Nonionic iodinated agents and gadolinium do cross the barrier but their movement is restricted because of high water solubility and larger molecular weights. Despite this, it is recommended to avoid using gadolinium where possible because there is little data regarding the long-term effect of such exposure.[69,70]

ANESTHETIC MANAGEMENT

Anesthetic management should be directed toward achievement and maintenance of maternal oxygenation and perfusion. Optimization of both will provide the best in utero conditions.[71] The pregnant patient is at increased risk for airway complications because of pregnancy-induced weight gain, breast tissue hypertrophy, and respiratory tract mucosal edema.[72] The incidence of difficult/failed intubation in obstetric anesthesia is 4 times higher than that in the surgical nonobstetric population.[73] The pregnant patient should be considered at risk for aspiration because of a full stomach from the second trimester. In the situation of trauma, a full stomach should always be considered. This consideration requires the use of rapid sequence induction and cricoid pressure for intubation. However, the use of cricoid pressure has been recently questioned because of both potential nonefficacy and distortion of laryngoscope view.[74] Guidelines recommend pharmacologic therapies to reduce acid aspiration,[75] but these are less suited to the emergency maternal trauma scenario. It is thus sensible to use methods to prevent clinically significant aspiration when possible, seek expert help before advanced airway management, and insert a tracheal tube of 0.5 to 1 mm internal diameter smaller than that used for nonpregnant woman of similar size.

Minute ventilation is approximately 30% higher in healthy women with singleton and twin pregnancies compared with nonpregnant women, and already during the first trimester, functional reserve capacity and expiratory reserve volume are lower by about 20% to 30%.[33] Because the pregnant trauma patient has lower respiratory reserves and the fetus can suffer easily from maternal hypoxia, early tracheal intubation has been advocated, with consideration for normal physiologic $Paco_2$ in pregnancy.[76] Induction drugs should be used with care to minimize vasodilation and hypotension. Propofol or ketamine are suitable, although both cross the placenta and can cause fetal depression.[77] Suxamethonium may be used to provide conditions for rapid intubation, and muscle relaxants do not cross the placenta in clinically relevant concentrations.[71] If suxamethonium is contraindicated (eg, with burns) rocuronium is also suitable.[78] The intubating dose of rocuronium is 1.2 mg/kg; however, the duration of action is relatively long.[79,80] Sugammadex (currently not licensed in the United States), which may be used to rapidly reverse rocuronium in cases of failed intubation, has been used in induction for CD but not for cases with ongoing pregnancy such as some maternal trauma situations.[81] The pediatrician caring for the neonate should be notified if drugs that traverse the placenta have been used (eg, opiates); temporary neonatal respiratory depression and flaccidity may occur.

RESCUE THERAPIES

Cesarean Delivery

About 2.4% to 7.2% of maternal trauma cases require CD shortly after trauma.[82–84] One study found that these cases have notably higher mortality rates than the general maternal trauma population (28.1%).[84]

In these cases maternal life may be at risk due to both obstetric and nonobstetric hemorrhage (ie, associated injuries).[84] Resuscitation and obstetric guidelines suggest that perimortem cesarean Delivery (PMCD) be considered within 4 minutes of maternal collapse for any cause, provided there is no evidence of return of spontaneous circulation.[85–87] This recommendation is based on physiologic evidence that compression of the vena cava by the gravid uterus may compromise maternal hemodynamics.[86,88] The concept of PMCD within 4 minutes of maternal arrest was introduced by Katz and colleagues.[89,90] In the first article discussing a possible time limit to good maternal and fetal outcomes, trauma constituted the cause of the arrest in less than 10% of the cases.[89] In 2 later articles, trauma was the most common cause of maternal death and accounted for about 20% of PMCD cases.[90,91] The paucity of reported cases prevents association between the cause of arrest and the likelihood of successful maternal return of spontaneous maternal circulation after PMCD. The role of PMCD for maternal salvage in traumatic cardiac arrest thus remains controversial. PMCD should, however, be considered for fetal salvage, that is, when maternal resuscitation efforts have been futile for 5 to 10 minutes and the fetus is likely to be viable (gestational age $\geq$23 weeks).

Extracorporeal Membranous Oxygenation

Use of extracorporeal membranous oxygenation (ECMO) for treatment of refractory hypoxemia or cardiac support in trauma has been limited by the difficulties of emergency vascular access, risk of hemorrhage, and lack of proof regarding benefit. Several investigators have suggested that ECMO therapy may be beneficial during pregnancy/in the early postpartaum period in H1N1-related hypoxemia,[92,93] massive thrombotic/amniotic fluid embolism,[94,95] and peripartum cardiomyopathy.[96] Only 1 case of successful ECMO therapy for maternal trauma has been reported.[97] This therapeutic option should thus be considered rescue therapy in the setting of maternal trauma with refractory hypoxemia.

MATERNAL OUTCOMES AND THE IMPACT OF PREGNANCY ON TRIAGE

Triage and Trauma Team Activation

Recommendations for field triage of injured patients cite pregnancy with a gestational age greater than 20 weeks as a criterion for patient transport to a Level I trauma center.[98] Recent assessment of the yield of these prehospital trauma triage guidelines through review of hospital discharge records revealed that major trauma was confirmed in only 1.5% (2 of 129) of the injured women transferred to Level I trauma centers because of pregnancy.[99] Many hospitals include pregnancy as a sole criterion for trauma team activation (TTA). For example, a survey of practice in the metropolitan Sydney area showed that 71% (5 of 7) of hospitals surveyed used this criterion, the only difference being slightly different gestational age cutoffs for TTA.[100] The presence of pregnancy is also a trigger for patient admission; pregnant women admitted for observation after trauma would not have been admitted in the absence of pregnancy.[16,32,101] Overtriage and overadmission because of the existence of a pregnant state may be the reasons for the low case fatality rates observed after maternal MVA. For example, one study found that among 188 of 352 pregnant trauma patients in

whom pregnancy was the sole indication for TTA (58%), none were admitted to the surgical service[102] and that among the pregnant patients with a gestational age less than 20 weeks, 94% (33 of 35) were not admitted.[102] Another study demonstrated that when pregnancy was the sole criterion for TTA, the mean injury severity score (ISS) of this population was 1.053 (range 1–4) and the only required surgical intervention was CD, which was performed in 3.5% of the patients (2 of 57).[83] If a decision is made to activate the trauma team based on pregnancy as the sole criterion, a 2-tiered system or reduced team approach may be suitable. This approach would take into consideration the erosion of adherence to trauma protocol because of low rates of significant injury.

Maternal Outcomes

Population-based studies show that among the women admitted to hospital after an MVA, about 0.003% are admitted to an intensive care unit and less than 0.01% die.[5,13] Deaths usually occur in the subgroup of women that have sustained bruising injuries to the abdomen, pelvis or lower back, pelvic fractures and/or intra-abdominal injuries and in the subgroup of women who deliver during the index admission.[5] Thus, the overall maternal mortality rates after trauma are not high (0%–3.8%),[18,19,48,82,103] but the clinician should be aware that there are certain factors associated with increased mortality rates. These include the need for CD shortly after trauma, penetrating trauma,[84] and lack of restraints during involvement in an MVA.[104] Head injuries,[16] lower GCSs,[84,105] higher ISSs,[49] associated internal injuries,[49] and shock on admission[84] are also associated with poorer maternal outcomes, as is greater maternal age.[49] Despite this, a study from the National Trauma Data Bank (2001–2005) suggests that mortality among pregnant women is overall lower than that among matched nonpregnant women. This difference has been attributed to protective hormonal and physiologic effect of pregnancy.[106] Cesarean delivery is more common in pregnant women who had been injured during pregnancy than among those who had not been injured (odds ratio, 1.27; 95% confidence interval [CI], 1.19–1.36).[50] The average time elapsing between the index trauma hospital arrival and CD is 5.6 hours.[84] Severely injured pregnant casualties have a significantly higher likelihood of CD than those with milder injury or control population (71.4% vs 18% and 18.9%, respectively, risk ratio, 3.8; 95%CI, 2.1–6.9).[107]

Between 9.2% and 16.2% of maternal trauma cases who are admitted to hospital are severely injured (ISS >8).[48,108,109] The severity of injury described in pregnancy is diverse and similar to those described in the nonpregnant population.[13] Pregnancy-related morbidity after trauma occurs in about 25% of maternal injury and may include placental abruption, uterine rupture, and CD despite prematurity, as described earlier.[110]

FETAL/NEONATAL OUTCOMES

Maternal trauma may affect fetal survival in the immediate posttrauma period, eventual pregnancy outcome, and later neonatal development. Early articles focused on describing the outcome of the pregnancy of interest; retrospective chart review included follow up until neonatal delivery or termination of the pregnancy.[104,111,112] More recent papers are population based and thus better reflect the true effect of maternal trauma on neonatal outcomes.[3,13,50]

According to hospital-based studies, the rate of fetal loss after maternal trauma ranges between 4.7% and 19.1%.[18,102,111,113] Rates of fetal loss described in this type of literature are biased by differing case mixes (ie, database, trauma center,

and nontrauma center), loss to follow-up, and case selection methods. Population-based studies suggest that there are 3.7 cases of fetal/neonatal loss directly due to maternal trauma per 100,000 live births.[13,114] MVAs are by far the most common known cause of trauma-associated fetal/neonatal loss and constitute more than 80% of cases,[114] but maternal injury resulting from domestic violence may also lead to poor fetal outcomes.[3,115] In addition to fetal loss, there may be an increased incidence of preterm birth and low birth weight among women injured during pregnancy,[50,116] although this finding is controversial.[4]

High maternal ISS is the only factor consistently associated with acute termination of pregnancy and/or fetal mortality after trauma (**Table 1**).[16,17,103,111–113,117] This association is highly sensitive but very nonspecific.[103] Several case reports suggest that 3-point restraints and deployed air bags caused direct fetal injury.[118–120] In larger studies, lack of restraints was associated with poorer neonatal outcomes.[17] Cohort studies also found no increased risk of adverse pregnancy outcomes with air bag deployment, but these studies may have been limited by the small number of cases.[121,122]

EDUCATION AND TRAINING

There is a dearth of educational strategies targeted toward prevention of maternal trauma (among the general public) and toward management of maternal trauma (among medical professionals). This paucity is likely due to lack of data regarding the process issues requiring address and the public health and economic implications of resultant maternal debilitation and/or pediatric critical illness.[123] Public education is beyond the scope of this article. Within the medical profession, there is evidence that practice simulations of obstetric catastrophes are beneficial to clinical performance.[124] Courses intended to develop and update (through simulation and assessment) the emergency skill set of the medical professionals who treat pregnant women do exist.[125,126] These MOET courses (Managing Obstetric Emergencies and Trauma),

Table 1
Studies of variables potentially associated with trauma-associated fetal loss

Variables Found Associated with Fetal Loss		Variables Found not to be Associated with Fetal Loss	
Variable	**Source**	**Variable**	**Source**
Severe hemorrhage and DIC	113	Maternal hemodynamic parameters	103,111,113
Shock (lactic acidosis)	111,117		
Loss of consciousness	18	Head injury	16,113,117
Low GCS	112	Low GCS	117
Pelvic injury	18	Abdominopelvic injury	113
Abdominal injury	16,111,117		
Gestational age	49	Gestational age	18
Nonviable pregnancy (<23 wk)	103		
Older maternal age	18		
Hypoxia	111	Use of restraints	18
Lower extremity injury	16	Position in vehicle	18
		Ejection from vehicle	18
		Speed	18
Vaginal bleeding	117	Abnormal uterine activity	117
		Abnormal FHR	117

originally developed in the United Kingdom, have been taught around the world but are not mandatory and not widely available. At present, the simulations and clinical drills that are recommended in the maternal safety educational program initiated by the American College of Obstetricians and Gynecologists (ACOG) include maternal cardiac arrest and perimortem CD but not maternal trauma.[127–129] It may be wise to consider adopting a similar educational route for management of maternal trauma. Importantly, if a decision is taken to pursue such a route, knowledge should be reinforced periodically; retention usually does not extend beyond 12 months.[130]

REFERENCES

1. Desjardins G. Management of the injured pregnant patient. Available at: http://www.trauma.org/archive/resus/pregnancytrauma.html. Accessed July 20, 2012.
2. Chang J, Elam-Evans LD, Berg CJ, et al. Pregnancy-related mortality surveillance–United States, 1991–1999. MMWR Surveill Summ 2003;52(2):1–8.
3. Fischer PE, Zarzaur BL, Fabian TC, et al. 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.
4. Virk J, Hsu P, Olsen J. Socio-demographic characteristics of women sustaining injuries during pregnancy: a study from the Danish National Birth Cohort. BMJ Open 2012;2(4). pii: e000826.
5. Vivian-Taylor J, Roberts CL, Chen JS, et al. Motor vehicle accidents during pregnancy: a population-based study. BJOG 2012;119(4):499–503.
6. Elliott DC, Rodriguez A. Cost effectiveness in trauma care. Surg Clin North Am 1996;76(1):47–62.
7. Prada SI, Salkever D, Mackenzie EJ. Level-I trauma center effects on return-to-work outcomes. Eval Rev 2012;36(2):133–64.
8. Palladino CL, Singh V, Campbell J, et al. Homicide and suicide during the perinatal period: findings from the National Violent Death Reporting System. Obstet Gynecol 2011;118(5):1056–63.
9. Sharps PW, Koziol-McLain J, Campbell J, et al. Health care providers' missed opportunities for preventing femicide. Prev Med 2001;33(5):373–80.
10. Hoyert DL. Maternal mortality and related concepts. National Center for Health Statistics. Vital Health Stat 3 2007;(33). Available at:. http://www.cdc.gov/nchs/data/series/sr_03/sr03_033.pdf. Accessed July 20, 2012.
11. Lisonkova S, Liu S, Bartholomew S, et al, Maternal Health Study Group of the Canadian Perinatal Surveillance System. Temporal trends in maternal mortality in Canada II: estimates based on hospitalization data. J Obstet Gynaecol Can 2011;33(10):1020–30.
12. Liu S, Rouleau J, Joseph KS, et al, Maternal Health Study Group of the Canadian Perinatal Surveillance System. Epidemiology of pregnancy-associated venous thromboembolism: a population-based study in Canada. J Obstet Gynaecol Can 2009;31(7):611–20.
13. Kvarnstrand L, Milsom I, Lekander T, et al. 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. Redelmeier DA, Bayoumi AM. Time lost by driving fast in the United States. Med Decis Making 2010;30:E12e9.
15. Patton GC, Coffey C, Sawyer SM, et al. Global patterns of mortality in young people: a systematic analysis of population health data. Lancet 2009;374(9693):881–92.

16. Ikossi DG, Lazar AA, Morabito D, et al. Profile of mothers at risk: an analysis of injury and pregnancy loss in 1195 trauma patients. J Am Coll Surg 2005;200: 49–56.
17. Klinich KD, Flannagan CA, Rupp JD, et al. Fetal outcome in motor-vehicle crashes: effects of crash characteristics and maternal restraint. Am J Obstet Gynecol 2008;198(4):450.e1–9.
18. Aboutanos MB, Aboutanos SZ, Dompkowski D, et al. Significance of motor vehicle crashes and pelvic injury on fetal mortality: a five-year institutional review. J Trauma 2008;65(3):616–20.
19. Patteson SK, Snider CC, Meyer DS, et al. The consequences of high-risk behaviors: trauma during pregnancy. J Trauma 2007;62(4):1015–20.
20. Martin SL, Macy RJ, Sullivan K, et al. Pregnancy-associated violent deaths: the role of intimate partner violence. Trauma Violence Abuse 2007;8(2):135–48.
21. Gazmararian JA, Adams MM, Saltzman LE, et al. The relationship between pregnancy intendedness and physical violence in mothers of newborns. The PRAMS Working Group. Obstet Gynecol 1995;85(6):1031–8.
22. Ronsmans C, Khlat M. Adolescence and risk of violent death during pregnancy in Matlab, Bangladesh. Lancet 1999;354(9188):1448.
23. Campero L, Walker D, Hernández B, et al. The contribution of violence to maternal mortality in Morelos, Mexico. Salud Publica Mex 2006;48(Suppl 2): S297–306 [in Spanish].
24. Krulewitch CJ, Pierre-Louis ML, de Leon-Gomez R, et al. Hidden from view: violent deaths among pregnant women in the District of Columbia, 1988-1996. J Midwifery Womens Health 2001;46(1):4–10.
25. Dannenberg AL, Carter DM, Lawson HW, et al. Homicide and other injuries as causes of maternal death in New York City, 1987 through 1991. Am J Obstet Gynecol 1995;172(5):1557–64.
26. Christiansen LR, Collins KA. Pregnancy-associated deaths: a 15-year retrospective study and overall review of maternal pathophysiology. Am J Forensic Med Pathol 2006;27(1):11–9.
27. Moracco KE, Runyan CW, Butts JD. Female intimate partner homicide: a population-based study. J Am Med Womens Assoc 2003;58(1):20–5.
28. By the American College of Surgeons Committee on Trauma. Chapter 12: "Trauma in women". In: Advanced trauma life support for doctors: Student Course Manual. 8th edition. Chicago: American College of Surgeons; 2008. p. 259–68.
29. Van Olden GD, Meeuwis JD, Bolhuis HW, et al. Clinical impact of advanced trauma life support. Am J Emerg Med 2004;22(7):522–5.
30. Shackford SR, Hollingworth-Fridlund P, Cooper GF, et al. The effect of regionalization upon the quality of trauma care as assessed by concurrent audit before and after institution of a trauma system: a preliminary report. J Trauma 1986;26(9):812–20.
31. ACOG educational bulletin. Obstetric aspects of trauma management. Number 251, September 1998. American College of Obstetricians and Gynecologists. Int J Gynaecol Obstet 1999;64:87–94.
32. Sela HY, Weiniger CF, Hersch M, et al. The pregnant motor vehicle accident casualty: adherence to basic workup and admission guidelines. Ann Surg 2011;254(2):346–52.
33. McAuliffe F, Kametas N, Costello J, et al. Respiratory function in singleton and twin pregnancy. BJOG 2002;109(7):765–9.
34. Bieniarz J, Gulin L, Arnt IC, et al. Aortoiliac compression by uterus containing hydrocephalic fetus. Obstet Gynecol 1968;31(1):90–6.

35. Kinsella SM, Lohmann G. Supine hypotensive syndrome. Obstet Gynecol 1994; 83(5 Pt 1):774–88.
36. Oyelese Y, Smulian JC. Placenta previa, placenta accreta, and vasa previa. Obstet Gynecol 2006;107(4):927–41.
37. Bowman M, Giles W, Deane S. Trauma during pregnancy-a review of management. Aust N Z J Obstet Gynaecol 1989;29:389–93.
38. Saule I, Hawkins N. Transfusion practice in major obstetric haemorrhage: lessons from trauma. Int J Obstet Anesth 2012;21(1):79–83.
39. Austin LM, Frush DP. Compendium of national guidelines for imaging the pregnant patient. AJR Am J Roentgenol 2011;197(4):W737–46.
40. ACOG Committee on Obstetric Practice. ACOG Committee Opinion. Number 299. Guidelines for diagnostic imaging during pregnancy. ACOG Committee on Obstetric Practice. Obstet Gynecol 2004;104:647–51.
41. Goodwin H, Holmes JF, Wisner DH. Abdominal ultrasound examination in pregnant blunt trauma patients. J Trauma 2001;50(4):689–94.
42. Sirlin CB, Casola G, Brown MA, et al. Us of blunt abdominal trauma: importance of free pelvic fluid in women of reproductive age. Radiology 2001;219(1):229–35.
43. Brown MA, Sirlin CB, Farahmand N, et al. Screening sonography in pregnant patients with blunt abdominal trauma. J Ultrasound Med 2005;24(2):175–81.
44. Richards JR, Ormsby EL, Romo MV, et al. Blunt abdominal injury in the pregnant patient: detection with US. Radiology 2004;233(2):463–70.
45. Houston LE, Odibo AO, Macones GA. The safety of obstetrical ultrasound: a review. Prenat Diagn 2009;29(13):1204–12.
46. Masselli G, Brunelli R, Di Tola M, et al. MR imaging in the evaluation of placental abruption: correlation with sonographic findings. Radiology 2011;259(1):222–30.
47. Baughman WC, Corteville JE, Shah RR. Placenta accreta: spectrum of US and MR imaging findings. Radiographics 2008;28(7):1905–16.
48. Schiff MA, Holt VL. Pregnancy outcomes following hospitalization for motor vehicle crashes in Washington State from 1989 to 2001. Am J Epidemiol 2005;161(6):503–10.
49. El-Kady D, Gilbert WM, Anderson J, et al. Trauma during pregnancy: an analysis of maternal and fetal outcomes in a large population. Am J Obstet Gynecol 2004;190(6):1661–8.
50. 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.
51. Ellingsen CL, Eggebø TM, Lexow K. Amniotic fluid embolism after blunt abdominal trauma. Resuscitation 2007;75(1):180–3.
52. Conde-Agudelo A, Romero R. Amniotic fluid embolism: an evidence-based review. Am J Obstet Gynecol 2009;201(5):445.e1–13.
53. Capogna G. Effect of epidural analgesia on the fetal heart rate. Eur J Obstet Gynecol Reprod Biol 2001;98(2):160–4.
54. Chandraharan E, Arulkumaran S. Prevention of birth asphyxia: responding appropriately to cardiotocograph (CTG) traces. Best Pract Res Clin Obstet Gynaecol 2007;21(4):609–24.
55. Grivell RM, Alfirevic Z, Gyte GM, et al. Antenatal cardiotocography for fetal assessment. Cochrane Database Syst Rev 2010;(1):CD007863.
56. Garite TJ, Simpson KR. Intrauterine resuscitation during labor. Clin Obstet Gynecol 2011;54(1):28–39.
57. Wylie BJ, D'Alton ME. Fetomaternal hemorrhage. Obstet Gynecol 2010;115(5): 1039–51.

58. Shetty MK. Abdominal computed tomography during pregnancy: a review of indications and fetal radiation exposure issues. Semin Ultrasound CT MRI 2010;31:3–7.
59. Nguyen CP, Goodman LH. Fetal risk in diagnostic radiology. Semin Ultrasound CT MRI 2012;33:4–10.
60. Schull WJ, Otake M. Cognitive function and prenatal exposure to ionizing radiation. Teratology 1999;59(4):222–6.
61. Wagner LK, Applegate K. ACR practice guideline for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation. In: American College of Radiology Practice guidelines & technical standards 2008 (resolution 26). Available at: http://www.who.int/tb/advisory_bodies/impact_measurement_taskforce/meetings/prevalence_survey/imaging_pregnant_arc.pdf.
62. Lockwood D, Einstein D, Davros W. Diagnostic imaging: radiation dose and patients' concerns. Cleve Clin J Med 2006;73(6):583–6.
63. Tremblay E, Thérasse E, Thomassin- Naggara I, et al. Quality initiatives. Guidelines for use of medical imaging during pregnancy and lactation. Radiographics 2012;32:897–912.
64. Wakeford R. Childhood leukaemia following medical diagnostic exposure to ionizing radiation in utero or after birth. Radiat Prot Dosimetry 2008;132(2): 166–74.
65. Yousefzadeh D, Ward M, Reft C. Internal barium shielding to minimize fetal irradiation in spiral chest CT: a phantom simulation experiment. Radiology 2006; 239:751–8.
66. ACOG Committee on Obstetric Practice. ACOG Committee Opinion, no. 299, September 2004 (replaces no. 158, September 1995): guidelines for diagnostic imaging during pregnancy. Obstet Gynecol 2004;104(3):647–51.
67. Brent RL. Saving lives and changing family histories: appropriate counseling of pregnant women and men and women of reproductive age, concerning the risk of diagnostic radiation exposures during and before pregnancy. Am J Obstet Gynecol 2009;200(1):4–24.
68. Wall BF, Meara JR, Muirhead CR, et al. Protection of pregnant patients during diagnostic medical exposures to ionising radiation: advice from the Health Protection Agency, the Royal College of Radiologists and the College of Radiographers. Documents of the Health Protection Agency: radiation, chemical and environmental hazards. United Kingdom, 2009.
69. Webb JA, Thomsen HS, Morcos SK, Members of Contrast Media Safety Committee of European Society of Urogenital Radiology (ESUR). The use of iodinated and gadolinium contrast media during pregnancy and lactation. Eur Radiol 2005;15(6):1234–40.
70. Medical Devices Agency. Guidelines for magnetic resonance diagnostic equipment in clinical use. London, England: Medicines and Healthcare products Regulatory Agency; 2002.
71. Weinberg L, Steele RG, Pugh R, et al. The pregnant trauma patient. Anaesth Intensive Care 2005;33(2):167–80.
72. Kuczkowski KM, Reisner LS, Benumof JL. Airway problems and new solutions for the obstetric patient. J Clin Anesth 2003;15:552–63.
73. Suresh M, Wali A. Failed intubation in obstetrics: airway management strategies [guest editorial]. Anesthesiol Clin North Am 1998;16:477–98.
74. De Souza DG, Doar LH, Mehta SH, et al. Aspiration prophylaxis and rapid sequence induction for elective cesarean delivery: time to reassess old dogma? Anesth Analg 2010;110(5):1503–5.

75. American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Practice guidelines for obstetric anesthesia. An updated report by the American Society of Anesthesiologists Task Force on Obstetric Anesthesia. Anesthesiology 2007;106:843–63.
76. Meroz Y, Elchalal U, Ginosar Y. Initial trauma management in advanced pregnancy. Anesthesiol Clin 2007;25(1):117–29.
77. Van de Velde M, Teunkens A, Kuypers M, et al. General anaesthesia with target controlled infusion of propofol for planned caesarean section: maternal and neonatal effects of a remifentanil-based technique. Int J Obstet Anesth 2004; 13(3):153–8.
78. Abu-Halaweh SA, Massad IM, Abu-Ali HM, et al. Rapid sequence induction and intubation with 1 mg/kg rocuronium bromide in cesarean section, comparison with suxamethonium. Saudi Med J 2007;28(9):1393–6.
79. Pühringer FK, Sparr HJ, Mitterschiffthaler G, et al. Extended duration of action of rocuronium in postpartum patients. Anesth Analg 1997;84(2): 352–4.
80. Gin T, Chan MT, Chan KL, et al. Prolonged neuromuscular block after rocuronium in postpartum patients. Anesth Analg 2002;94(3):686–9.
81. Williamson RM, Mallaiah S, Barclay P. Rocuronium and sugammadex for rapid sequence induction of obstetric general anaesthesia. Acta Anaesthesiol Scand 2011;55(6):694–9.
82. Rogers FB, Rozycki GS, Osler TM, et al. A multi-institutional study of factors associated with fetal death in injured pregnant patients. Arch Surg 1999; 134(11):1274–7.
83. Aufforth R, Edhayan E, Dempah D. Should pregnancy be a sole criterion for trauma code activation: a review of the trauma registry. Am J Surg 2010; 199(3):387–90.
84. Morris JA Jr, Rosenbower TJ, Jurkovich GJ, et al. Infant survival after cesarean section for trauma. Ann Surg 1996;223(5):481–91.
85. Soar J, Perkins GD, Abbas G, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: Electrolyte abnormalities, poisoning, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. Resuscitation 2010;81(10):1400–33.
86. Vanden Hoek TL, Morrison LJ, Shuster M, et al. Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2010;122(18 Suppl 3): S829–61.
87. RCOG, maternal collapse in pregnancy and the puerperium green-top guideline no. 56. 2011. p. 24. Available at: http://digitalrepository.e-medicinafetal.org/bitstream/10615/261/1/Maternal%20collapse%20in%20pregnancy%20and%20the%20puerperium%20RCOG%202011-3.pdf. Accessed February 9, 2011.
88. Ueland K, Novy MJ, Peterson EN, et al. Maternal cardiovascular dynamics, IV: the influence of gestational age on the maternal cardiovascular response to posture and exercise. Am J Obstet Gynecol 1969;104:856–64.
89. Katz VL, Dotters DJ, Droegemueller W. Perimortem caesarean delivery. Obstet Gynecol 1986;68(4):571–6.
90. Katz V, Balderston K, DeFreest M. Perimortem caesarean delivery: were our assumptions correct? Am J Obstet Gynecol 2005;192(6):1916–21.
91. Einav S, Kaufman N, Sela HY. Maternal cardiac arrest and perimortem caesarean delivery: evidence or expert-based? Resuscitation 2012;83(10):1191–200.

92. Nair P, Davies AR, Beca J, et al. Extracorporeal membrane oxygenation for severe ARDS in pregnant and postpartum women during the 2009 H1N1 pandemic. Intensive Care Med 2011;37(4):648–54.
93. Dubar G, Azria E, Tesnière A, et al, French Registry on 2009 A/H1N1v during pregnancy. French experience of 2009 A/H1N1v influenza in pregnant women. PLoS One 2010;5(10). pii: e13112.
94. Ho CH, Chen KB, Liu SK, et al. Early application of extracorporeal membrane oxygenation in a patient with amniotic fluid embolism. Acta Anaesthesiol Taiwan 2009;47(2):99–102.
95. Weinberg L, Kay C, Liskaser F, et al. Successful treatment of peripartum massive pulmonary embolism with extracorporeal membrane oxygenation and catheter-directed pulmonary thrombolytic therapy. Anaesth Intensive Care 2011;39(3):486–91.
96. Smith IJ, Gillham MJ. Fulminant peripartum cardiomyopathy rescue with extracorporeal membranous oxygenation. Int J Obstet Anesth 2009;18(2):186–8.
97. Plotkin JS, Shah JB, Lofland GK, et al. Extracorporeal membrane oxygenation in the successful treatment of traumatic adult respiratory distress syndrome: case report and review. J Trauma 1994;37(1):127–30, 7.
98. Sasser SM, Hunt RC, Sullivent EE, et al, National Expert Panel on Field Triage, Centers for Disease Control, Prevention (CDC). Guidelines for field triage of injured patients. Recommendations of the National Expert Panel on Field Triage. MMWR Recomm Rep 2009;58(RR-1):1–35.
99. Cox S, Smith K, Currell A, et al. Differentiation of confirmed major trauma patients and potential major trauma patients using pre-hospital trauma triage criteria. Injury 2011;42(9):889–95.
100. Smith J, Caldwell E, Sugrue M. Difference in trauma team activation criteria between hospitals within the same region. Emerg Med Australas 2005; 17(5–6):480–7.
101. Drost TF, Rosemurgy AS, Sherman HF, et al. Major trauma in pregnant women: maternal/fetal outcome. J Trauma 1990;30(5):574–8.
102. Greene W, Robinson L, Rizzo AG, et al. Pregnancy is not a sufficient indicator for trauma team activation. J Trauma 2007;63(3):550–5.
103. Theodorou DA, Velmahos GC, Souter I, et al. Fetal death after trauma in pregnancy. Am Surg 2000;66(9):809–12.
104. Esposito TJ, Gens DR, Smith LG, et al. Trauma during pregnancy. A review of 79 cases. Arch Surg 1991;126(9):1073–8.
105. Corsi PR, Rasslan S, de Oliveira LB, et al. Trauma in pregnant women: analysis of maternal and fetal mortality. Injury 1999;30(4):239–43.
106. John PR, Shiozawa A, Haut ER, et al. An assessment of the impact of pregnancy on trauma mortality. Surgery 2011;149(1):94–8.
107. Schiff MA, Holt VL, Daling JR. Maternal and infant outcomes after injury during pregnancy in Washington State from 1989 to 1997. J Trauma 2002;53(5): 939–45.
108. Curet MJ, Schermer CR, Demarest GB, et al. Predictors of outcome in trauma during pregnancy: identification of patients who can be monitored for less than 6 hours. J Trauma 2000;49(1):18–25.
109. Aboutanos SZ, Aboutanos MB, Dompkowski D, et al. Predictors of fetal outcome in pregnant trauma patients: a five-year institutional review. Am Surg 2007;73(8): 824–7.
110. Trivedi N, Ylagan M, Moore TR, et al. Predicting adverse outcomes following trauma in pregnancy. J Reprod Med 2012;57(1–2):3–8.

111. Hoff WS, D'Amelio LF, Tinkoff GH, et al. Maternal predictors of fetal demise in trauma during pregnancy. Surg Gynecol Obstet 1991;172(3):175–80.
112. Kissinger DP, Rozycki GS, Morris JA Jr, et al. Trauma in pregnancy. Predicting pregnancy outcome. Arch Surg 1991;126(9):1079–86.
113. Ali J, Yeo A, Gana TJ, et al. Predictors of fetal mortality in pregnant trauma patients. J Trauma 1997;42(5):782–5, 19.1%.
114. Weiss HB, Songer TJ, Fabio A. Fetal deaths related to maternal injury. JAMA 2001;286(15):1863–8.
115. Tinker SC, Reefhuis J, Dellinger AM, et al. Maternal injuries during the periconceptional period and the risk of birth defects, National Birth Defects Prevention Study, 1997-2005. Paediatr Perinat Epidemiol 2011;25(5):487–96.
116. Shah PS, Shah J, Knowledge Synthesis Group on Determinants of Preterm/LBW Births. Maternal exposure to domestic violence and pregnancy and birth outcomes: a systematic review and meta-analyses. J Womens Health (Larchmt) 2010;19(11):2017–31.
117. Shah KH, Simons RK, Holbrook T, et al. Trauma in pregnancy: maternal and fetal outcomes. J Trauma 1998;45(1):83–6.
118. Bard MR, Shaikh S, Pestaner J, et al. Direct fetal injury due to airbag deployment and three-point restraint. J Trauma 2009;67(4):E98–101.
119. Nguyen CS, Chase DM, Wing DA. Severe fetal skull fracture and death subsequent to a motor vehicle crash with frontal airbag deployment. J Trauma 2009; 67(6):E220–1.
120. Schultze PM, Stamm CA, Roger J. Placental abruption and fetal death with airbag deployment in a motor vehicle accident. Obstet Gynecol 1998;92(4 Pt 2): 719.
121. Schiff MA, Mack CD, Kaufman RP, et al. The effect of air bags on pregnancy outcomes in Washington State: 2002-2005. Obstet Gynecol 2010;115(1):85–92.
122. 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.
123. Shudy M, de Almeida ML, Ly S, et al. Impact of pediatric critical illness and injury on families: a systematic literature review. Pediatrics 2006;118(Suppl 3): S203–18.
124. Cass GK, Crofts JF, Draycott TJ. The use of simulation to teach clinical skills in obstetrics. Semin Perinatol 2011;35(2):68–73.
125. Johanson RB, Menon V, Burns E, et al. Managing obstetric emergencies and trauma (MOET) structured skills training in Armenia, utilising models and reality based scenarios. BMC Med Educ 2002;2:5.
126. Jyothi NK, Cox C, Johanson R. Management of obstetric emergencies and trauma (MOET): regional questionnaire survey of obstetric practice among career obstetricians in the United Kingdom. J Obstet Gynaecol 2001;21(2):107–11.
127. American College of Obstetricians, Gynecologists. ACOG Practice Bulletin: Clinical Management Guidelines for Obstetrician-Gynecologists Number 76, October 2006: postpartum hemorrhage. Obstet Gynecol 2006;108(4):1039–47.
128. Argani CH, Eichelberger M, Deering S, et al. The case for simulation as part of a comprehensive patient safety program. Am J Obstet Gynecol 2012;206(6): 451–5.
129. Lipman SS, Daniels KI, Arafeh J, et al. The case for OBLS: a simulation-based obstetric life support program. Semin Perinatol 2011;35(2):74–9.
130. Yang CW, Yen ZS, McGowan JE, et al. A systematic review of retention of adult advanced life support knowledge and skills in healthcare providers. Resuscitation 2012;83(9):1055–60.