# Pregnancy and blast injury

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## Abstract

- Although management of trauma in pregnancy has been well documented, there is little in the literature specifically addressing blast effects in pregnant casualties.
- Defence personnel providing health support in an asymmetric war-fighting environment are increasingly likely to find themselves managing civilian casualties, including many pregnant women, particularly in societies characterised by much higher fertility rates than in Australia.
- An understanding of the physiological changes of pregnancy will inform those providing advanced resuscitation to the pregnant blast victim.
- The uteroplacental interface is particularly vulnerable to primary blast effect. Assessment of uteroplacental function is based on history and clinical examination. Decision to deliver may be a difficult judgement, and liaison with an obstetrician may be appropriate.
- There are a range of resources available to personnel dealing with pregnant casualties, including pregnancy records carried by many pregnant women, and web-based management protocols covering a range of critical care issues in such casualties.


*ADF Health 2008; 9: 79-83*

OBSTETRIC CASES are frequently encountered on operations. Caesarean section was the second most common surgical procedure performed during Operation Bel Isi on the island of Bougainville.[1] Pregnant local nationals continue to be potential casualties in the Middle East Area of Operations. Trauma in pregnancy has significant consequences for both maternal and fetal outcome and has been previously reviewed in the literature.[2,3] More recently, civilian casualties resulting from the use of improvised explosive devices are being encountered. Such devices are frequently deployed in areas such as bus stops, mosques and markets where it is likely that many pregnant women will be among the civilian population present. Deployed military surgical personnel may have limited experience of obstetrics in general, and the prospect of dealing with blast injury in a pregnant casualty can be challenging. An awareness of the obstetric issues that may be encountered following blast injury will assist preparedness.

## Physiological changes of pregnancy

Pregnancy results in profound changes to all body systems.[4] Blood volume increases by 30%–50% by term, while red blood cell mass increases by only 10%–20%. There is a resulting physiological "anaemia of pregnancy". Cardiac output increases by 30%–50% through a combination of increased heart rate and stroke volume. This increased cardiac output provides for the uteroplacental blood flow of around 600 mL/min, together with increased blood flow to kidneys and other organ systems. Notwithstanding increased cardiac output, reduction in peripheral vascular resistance results in a fall in blood pressure, which reaches its low point late in the second trimester and returns to near-normal levels by term.[4]

There is an overall increase in extracellular fluid during pregnancy and generalised oedema is common, although it may be marked in pathological conditions such as pre-eclampsia. Consequently, assessment of volume status is complex in a pregnant woman who is oedematous, tachycardic and with a relatively reduced blood pressure.

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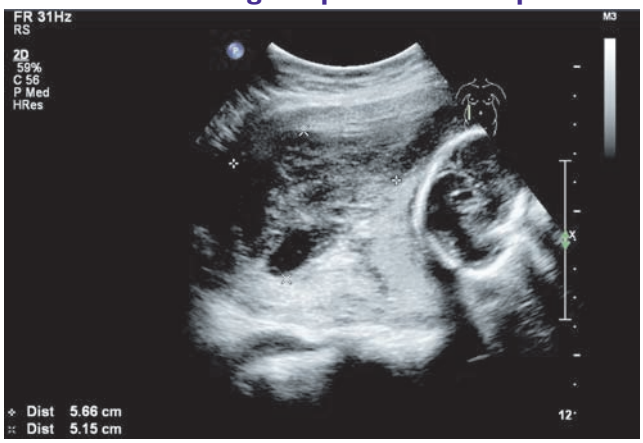
Pregnancy is a hypercoagulable state — presumably a survival advantage during the delivery process. This hypercoagulability is reflected in increased clotting factors and fibrinogen. Venous thromboembolism remains a significant cause of maternal mortality in the developed world. A physiologically raised white cell count in pregnancy may cause confusion in assessment of sepsis.

Around 15% of the population have Rhesus-negative blood. In most cases, the partners of pregnant Rhesus-negative women will be Rhesus-positive, and so too the fetus. Feto-maternal haemorrhage at the time of delivery or trauma in such casualties may result in maternal sensitisation and the production of anti-D antibodies. This outcome greatly complicates future pregnancies for such women, but may be prevented by appropriate administration of anti-D.

Minute ventilation increases by 50%–60% in pregnancy, with a reduction in functional residual capacity caused by diaphragmatic elevation and lower chest wall widening as a result of the gravid abdomen.[5] Increased physiological demands generally result in a 60% increase in oxygen consumption which, when considered with the decline in overall respiratory reserve, places the pregnant woman at increased risk of desaturating during anaesthesia or trauma

**1 Ultrasound image of placental abruption**




*Area of clot is demarcated by cursors laying above and to the left of placenta and fetal parts.*

management. Tachypnoea results in a relative respiratory alkalosis. Generalised redistribution of fluid to the extravascular compartment in pregnancy further complicates airway management. An oedematous airway in a casualty with a large abdominal mass presents specific airway challenges.

Renal blood flow is increased by up to 50% in pregnancy, with a resulting reduction in the reference range for urea and creatinine. High normal results from the non-pregnant reference range may represent significant renal abnormality in the pregnant casualty.

Anatomical changes in pregnancy can cause significant consequences if not recognised. A supine posture in late pregnancy may result in aortocaval compression, hypotension and loss of consciousness. Lateral tilt with a wedge is an effective countermeasure. Blood pressure assessment during pregnancy should be performed with the patient in a sitting position to negate confounding postural effects.

## Complications in pregnancy

Common pregnancy complications include maternal obstetric medical issues such as hypertension and pre-eclampsia, and gestational diabetes. The latter has become more prevalent as the average body mass index in the developed world increases. Fetal growth restriction is detected both clinically and by ultrasound imaging as part of the antenatal care of pregnant women. It is frequently the result of placental insufficiency caused either by environmental factors such as poor nutrition or cigarette smoking, or by abnormal placentation associated with conditions such as pre-eclampsia or antiphospholipid syndrome.

Antepartum haemorrhage and preterm labour are common emergent presentations in pregnancy that practitioners might face on deployment. Distinction between the two most significant causes of antepartum haemorrhage, namely placenta praevia and placental abruption, will assist in determining management, which will often be operative. Preterm labour remains a challenge for obstetric practitioners in all parts of the world. Distinguishing true threatened premature labour from the discomforts associated with normal pregnancy remains a common part of the practitioner's clinical day.

## Obstetrics in the deployed environment

Obstetrics in the developed world seems to increasingly revolve around overweight, nulliparous women attempting to deliver their first, sometimes macrosomic baby relatively late in their reproductive life. About a third of such women ultimately have an abdominal delivery. In contrast, obstetrics in less developed countries revolves around the complications of grand multiparity, such as fetal malpresentation and haemorrhage, and the complications of poor environment, such as infectious disease and poor nutrition. In such areas, an absence of diagnostic infrastructure to allow for assessment of fetal growth and development results in the birth of neonates with a range of problems not usually encountered in Australia. The challenge for developed-world practitioners is to appropriately adapt their practice to these changed conditions.

## Pregnancy and blast injury

The pathophysiology and mechanism of blast injury have been well documented in the scientific literature, particularly since the Oklahoma City bombing in 1995, the World Trade Center attacks in 2001 and the Madrid bombing in 2004.[6,7] Similarly, there is much in the literature concerning the physiological and clinical issues associated with trauma in pregnancy.[2,4] However, little has been published that specifically addresses blast injury in relation to pregnancy.

Primary blast injury results from the pressure wave generated by the explosion. A wave of increased pressure moves out from the point of explosion and generates very high pressures in tissues. As gas is especially compressible, gas-containing structures such as the bowel are particularly vulnerable. The high pressures cause rapid compression of tissue, leading to damage from shearing forces. The pressure wave generated by a blast is especially damaging to the air-filled pulmonary structures, and oxygen exchange can be compromised at a number of levels. The physiological changes of pregnancy reduce the redundancy in the respiratory system, increasing the vulnerability of the pregnant casualty as pregnancy advances.

Primary blast effect may lead to placental abruption as the shock wave passes through the interface between the denser myometrium and the less dense placental tissue. Placental abruption may be manifest, as revealed by vaginal bleeding, or concealed, with retroplacental haematoma formation (Box 1). Abruption is painful, with the patient usually having a rigid, tender uterus. Considerable blood loss may result in shock,

fetal demise and, potentially, disseminated intravascular coagulation. A consumptive coagulopathy may be triggered by the significant blood loss occurring in the retroplacental space.

Secondary blast injury relates to trauma from flying objects, while tertiary blast injury results from victims being thrown against other objects due to the force of the explosion. Secondary and tertiary blast effects may result in fractures in the pregnant patient. Pelvic fractures in pregnant women imply significant forces, which will often be associated with fetal or uteroplacental trauma. Coexisting fetal skull fractures have been reported in cases of maternal pelvic fracture, necessitating fetal delivery by caesarean section.[8] Secondary blast effects may also result in trauma or compression to the uterus, which is filled with amniotic fluid. If amniotic fluid gains access to the intravascular space, an amniotic fluid embolism may result, with maternal collapse and disseminated intravascular coagulation often following.

## Assessment and resuscitation of the pregnant blast victim

Pregnant patients with major trauma should be assessed in accordance with the Australasian Early Management of Severe Trauma guidelines, with performance of a primary survey before detailed history taking.[9]

Obstetric history, if available, is of considerable value and will greatly assist evaluation. In an Australian setting, many patients carry with them their full obstetric record containing data on due date and pregnancy progress, as well as scan and blood results. History taking should establish gestation and pregnancy issues, together with comorbidities. Potential fetal viability should be established. Clinical examination especially relevant to pregnancy includes abdominal assessment. In advanced pregnancy, the gravid abdomen displaces abdominal organs upward and away from underlying organs. Signs of peritonism may be absent or difficult to elicit. History of uterine pain and contractions or of vaginal discharge or bleeding should be sought.

Vaginal assessment may be necessary, especially where fluid or blood loss is reported. Digital vaginal examination must not be performed if there is any suggestion of placenta praevia. Speculum vaginal examination will often confirm the rupture of the membranes, with liquor pooling visible in the posterior fornix. The presence of ruptured membranes is a relative contraindication to digital vaginal examination (due to the risk of introducing infection) but may be necessary to assess cervical dilation. Antibiotic administration should be considered.[10] Reference to an existing set of guidelines will assist in these cases; such protocols guide appropriate prescription for doctors who are unfamiliar with those antibiotics (and other drugs) that are best avoided in pregnancy. Identification of the relevant protocols should be done before deployment; many include specific reference to pregnancy trauma management, are available on the Internet and are continually updated by the host organisation.

Ultrasound can be used to establish placental location and presence or absence of the fetal heart beat. These findings can be elicited by a trained operator using a portable field scanner, such as those made by SonoSite (Bothell, Wash, USA). Predeployment training of medical personnel should include the operation of field ultrasonography, including obstetric scanning. The primary role of a portable ultrasound scanner is to perform FAST (focused assessment with sonography for trauma) scanning, but obstetric scanning of local nationals has also been a major application on operational deployments.

Where cardiotocography is available, it should be used for at least 4 hours to provide reassurance about fetal wellbeing, but fetal monitoring of up to 24 hours is recommended in significant trauma cases.[4] However, cardiotocography is unlikely to be readily available in the military environment, and reassurance of fetal wellbeing will be achieved through a combination of clinical and ultrasonographic assessment and intermittent fetal auscultation.

Where available, computerised tomography (CT) evaluation is an adjunct to other diagnostic modalities in abdominal trauma, such as ultrasound or diagnostic peritoneal lavage (DPL). In a stable patient, CT evaluation may avoid the need for DPL and is most specific for organ injury in abdominal trauma.[9] CT may miss some gastrointestinal, diaphragmatic or splenic injuries, and where the patient is unstable, laparotomy is indicated. CT is essential in assessing head injuries and is an adjunct to other modalities in assessing chest trauma.

## Multiple injuries in the pregnant casualty

Multiple injuries in a pregnant casualty present clinicians with particular challenges, and there may be a need to weigh the interests of the casualty against those of the fetus when stratifying the surgical approach. Where there is co-existing chest and abdominal trauma, the thoracic and trauma surgeon's views as to the priority of effort will usually best guide management. Maternal salvage is ultimately the priority over fetal rescue. These interests coalesce where there is predominantly abdominal trauma, with early operative delivery being in both maternal and fetal best interests.

## Airway and chest factors

Airway management in pregnant patients can be a considerable challenge. Primary blast injury may produce a range of pulmonary or mediastinal effects, resulting in impaired gas exchange.[11] Similarly, secondary or tertiary blast effects may result in neurological injury, with resulting impaired consciousness. Establishment of a definitive airway should occur with consideration of the particular issues in pregnant patients. Clearing the airway is of particular importance due to

the increased risk of gastro-oesophageal reflux and aspiration of stomach contents. Pregnant women have delayed gastric emptying and a reduced gastro-oesophageal sphincter tone. However, the airways are oedematous, and endotracheal intubation can be particularly challenging in a pregnant patient, especially with an increased body mass index. An obstetric laryngoscope blade should be on hand to be used if necessary (Box 2). These blades will not necessarily be found in standard equipment sets, and consideration should be given to including them before deployment. The risk of failed intubation is increased in such patients, and personnel should refresh their failed intubation drills. A laryngeal mask may be a better option in some patients than the risk of losing an airway after a failed intubation attempt. Cricoid pressure should be employed during intubation to prevent aspiration; although it should be released if the patient begins to vomit, due to the risk of oesophageal rupture.

The tachypnoeic pregnant woman with her increased oxygen requirement is especially vulnerable to pulmonary barotrauma from the primary blast wave effect or, indeed, to chest wall injury from secondary and tertiary blast effects. Supplemental oxygen is required in all pregnant blast victims. Chest x-ray and, if available, CT should be used to assess for barotrauma and other chest trauma. While radiation exposure is of relevance in pregnant casualties, the need to assess the patient outweighs the risk from the relatively low dose of radiation from a chest x-ray. A chest x-ray involves about 0.2 mSv of radiation, compared with the annual background radiation of around 2–3 mSv. The pregnant abdomen can be shielded from radiation to some extent with a lead apron.

In a pregnant blast casualty with dyspnoea, cough or pulmonary oedema, amniotic fluid embolism or pulmonary embolism should be considered. Amniotic fluid embolism may follow trauma and has a significant mortality rate, in excess of 50%. Pregnancy predisposes to pulmonary embolism, which is a leading cause of overall maternal mortality in the developed world.

Chest wall trauma may necessitate placement of a chest drain. Anatomical changes associated with pregnancy need to be considered — drainage tubes need to be placed two interspaces above their usual position in a non-pregnant patient, to avoid sub-diaphragmatic injury.

## Circulatory factors

There is potential for massive blood loss, and intravenous access should be secured with multiple large-bore cannulas. The greater tendency for fluid to find its way to the extravascular compartment in pregnancy dictates that colloid rather than crystalloid is advantageous in resuscitating a pregnant casualty. O-negative blood must be used where the patient's blood group is unknown. In a Rhesus-negative woman, Rhesus sensitisation by transfusion with Rhesus-positive blood may have disastrous consequences for her future obstetric outcomes.

Cardiopulmonary resuscitation (CPR) in advanced pregnancy can be complicated by aortocaval compression if the patient is prone. Indeed, effective CPR will be so difficult in this situation that performance of operative delivery has been advocated not only for fetal salvage (required within about 10 minutes of cardiorespiratory arrest if the fetus is to have a chance of survival) but also to allow effective maternal resuscitation. Isolated case reports suggest that such desperate measures will on occasion allow for maternal salvage.[12]

Fluid resuscitation in pregnancy is especially complex in pre-eclampsia. Were a blast victim to be also suffering pre-eclampsia, those managing her volume status would be dealing with a casualty with reduced intravascular volume secondary to the pre-eclampsia, and with increased peripheral vascular resistance and increased blood pressure. Pre-eclampsia can be associated with either pre-renal or intrinsic renal compromise, and urine output can be an unreliable indicator of volume status. In these cases, fluid resuscitation should be done cautiously to avoid administration of excess fluids and pulmonary oedema.

**2 Laryngoscope blade**

*The McCoy laryngoscope blade is an example of a modified laryngoscope suitable for obstetric intubation. The levering tip allows for indirect elevation of the epiglottis and usually improved laryngeal view.*

## Abdominal trauma

Gastrointestinal structures, being air-filled, are susceptible to primary blast injury. Assessment of the pregnant blast casualty with an acute abdomen is a clinical challenge. Uterine fundal palpation will confirm the gestation established in the history and establish the potential for placental abruption, with a tender, rigid uterus raising the possibility of that diagnosis. Auscultation for a fetal heart beat can be conducted with a standard stethoscope, a Doppler device or using a portable ultrasound scanner. Clinical signs of peritonism may be masked in later pregnancy by the tenting of the abdominal wall by the gravid uterus and the displacement of the bowel in particular from its usual intra-abdominal position. In a significant blast injury, there may be concurrent uteroplacental and bowel injuries.

Where an antepartum haemorrhage has occurred, prompt resuscitation and often

## Key considerations

- Pregnancy is more prevalent in civilian populations in most operational areas than in Australia. If management of civilian casualties is an implied task, expect some to be pregnant.
- Asymmetric warfare increases the risk of civilian casualties presenting to military health facilities for management.
- Pregnancy increases vulnerability to the primary and secondary effects of a blast.
- Deploying organisations should consider the pregnancy-specific equipment, drugs, protocols and skills that may be required on operations.

fetal delivery are required. A clinical distinction between abruption and placenta praevia may inform management. Minor placental abruption may on occasion be managed expectantly, especially if the fetus is preterm. The decision of whether or not to deliver in these circumstances can be a difficult judgement, often exercised after receiving advice from an experienced obstetrician.

The Kleihauer test performed on a blood sample establishes the extent of feto-maternal haemorrhage resulting from placental abruption and, in Rhesus-negative women, whether the standard dose of anti-D will suffice. Where pregnant casualties are a possibility in an area of operations, the laboratory capability should be prepared to perform the relatively simple Kleihauer test and hold a stock of anti-D. Any Rhesus-negative woman with a history of trauma or vaginal bleeding should receive an appropriate dose of anti-D to minimise the risk of Rhesus sensitisation.

Aside from placental abruption, the main differential diagnosis in significant antepartum haemorrhage is that resulting from placenta praevia. Placental attachment is abnormal when the placenta is suboptimally located, such as to the lower uterine segment. Patients with placenta praevia are potentially at increased risk of bleeding following secondary blast effects. Placenta praevia is generally clinically distinguished from abruption by the relative absence of uterine pain and tenderness. Bleeding from placenta praevia can range from minor to torrential; in the latter case, operative delivery may be life-saving.

Laparotomy in the third trimester for a non-obstetric indication such as bowel trauma raises the issue of caesarean delivery of the fetus at the time of operation. If bowel or other intra-abdominal trauma is a possibility, a midline incision should be performed, even if the primary intention is to perform a caesarean. The risks of preterm delivery must be weighed against the risk to the fetus of remaining in utero; the threshold for delivery lowers as gestation advances. Cases must be managed on their individual merits, but in general terms, caesarean delivery at the time of laparotomy will often be a better option than attempting continued monitoring of a fetus in utero in an unstable patient. An added factor in this difficult judgement is the relative ability of the available infrastructure and personnel to deal with a preterm neonate. On occasion, such factors may result in the fetus remaining in utero where otherwise delivery might have occurred.

## Evacuation considerations

Where there are no overwhelming injuries, local facilities may well be best placed to provide appropriate care for pregnant casualties. Local midwives will be experienced in caring for pregnant women in an austere environment. Cultural and language issues will also be minimised.

Care should be taken to minimise the chance that delivery will occur while a casualty is in transit. The limited space in an aircraft greatly complicates delivery and there are unlikely to be resources to either resuscitate the neonate or manage a maternal complication such as postpartum haemorrhage. Multiparous patients may labour very rapidly. Vaginal assessment may need to be repeated on the flight line immediately before loading the patient to ensure that cervical change has not occurred in the time from the decision being made to the actual evacuation. Surface evacuation may provide a more flexible option, but security considerations will often be the determinant.

## Competing interests

None identified.

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*(Received 24 Aug 2008, accepted 13 Oct 2008)* ❑