ORIGINAL ARTICLE

Stanford M. Goldman

Overview of emergency radiological management of the pregnant patient, especially the traumatized pregnant patient

Abstract Both traumatic and nontraumatic acute emergencies are seen in hospitals in women of child-bearing age. The effects of radiation are theoretically most deleterious from 10 days after conception until roughly the end of the first trimester. However, there should be no hesitation about performing appropriate emergency imaging studies at any time during pregnancy. If time permits, the presence and age of the fetus should be determined through physical examination, appropriate laboratory studies, and the obtaining of adequate medical historical information. Imaging studies can be roughly classified into two main categories, those with minimal radiation effect and those that may expose the fetus to significant potential ionizing energy. The radiologist must be responsible for the determination of the most appropriate studies needed and in what sequence. Traumatized pregnant patients especially require maternal and fetal monitoring prior to arrival at the hospital and throughout the hospital stay. Fetal demise is a significant risk in case of both minor and major trauma. Maternal survival is the most significant factor in fetal well-being, with a fetal death approaching 80 % in cases of maternal shock and almost 100 % where there is partial or complete abruptio placentae. Properly performed imaging of the pregnant female, where the uterus is not likely to be exposed to ionizing radiation, should be cause little concern. Depending on the clinical presentation, appropriate first images might include a cervical spine, a portable chest film, an abdominal film, and a lateral decubitus view to check for suspected bowel perforation. This should be rapidly followed by fetal and then maternal ultrasonography. Overall, CT may be the best single abdominal study for severe abdominal problems where multiple organ damage is suspected. MRI for neurological disease and carefully monitored of selective vascular embolization for life-threatening abdominal bleeding are other important legitimate imaging studies.

Key words Emergency medical service system – Trauma – Kidney injuries – Ureter injuries – Bladder rupture – Pregnancy – Irradiation in pregnancy
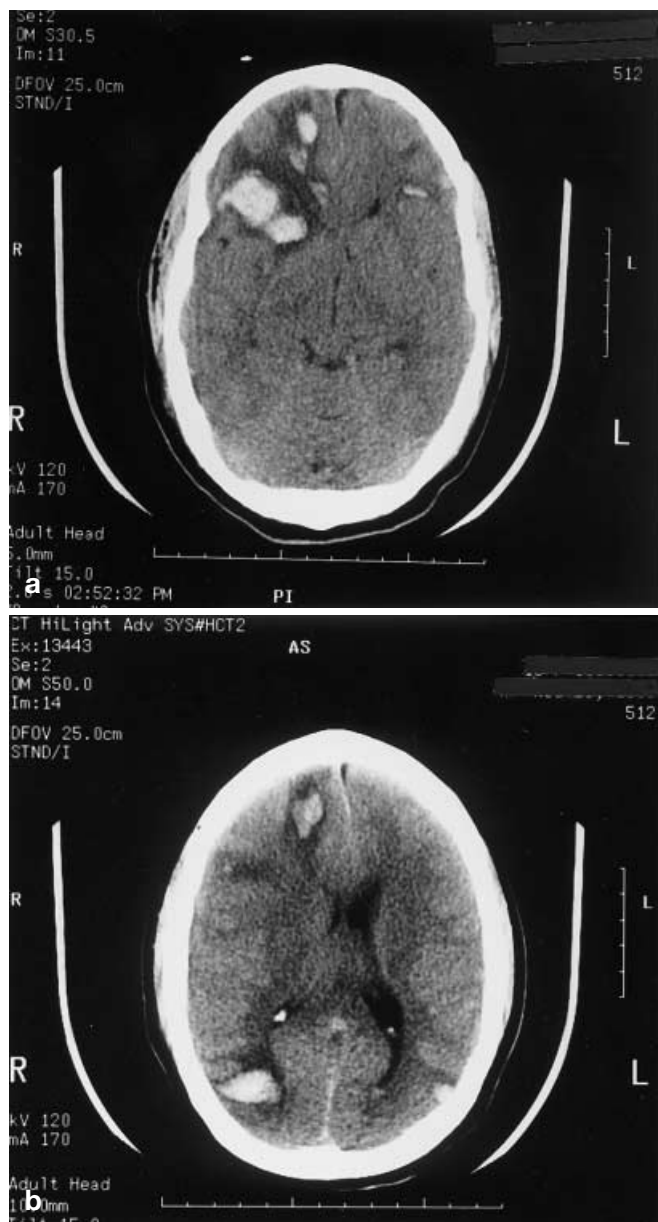
S.M. Goldman (✉)
Department of Radiology,
The University of Texas at Houston Medical School,
6431 Fannin, MSB 2.132, Houston, Texas 77030, USA
Tel.: + 1-713-500 77 00
Fax: + 1-713-5007639

Introduction

Trauma is the leading nonobstetrical cause of maternal mortality during pregnancy (up to 22 % of deaths) [1, 2]. It should be recognized that an accidental injury occurs in the course of 6–7 % of all pregnancies, with the highest frequency during the last trimester [2, 3]. In two out of three cases the mechanism of injury is an automobile accident. Physical abuse is the second most common cause of trauma [4].

Studies have demonstrated that 0.3–0.4 % of traumatized pregnant women need hospitalization [3] and that 24 % of pregnant females with major injuries fail to survive their injuries [5]. Shock, skull fractures, cerebral contusion, intracerebral hemorrhage (Fig. 1), spinal column fracture (Fig. 2) or injury, chest injuries (Fig. 3) needing a thoracotomy or tube thoracostomy, abdominal visceral or genitourinary injury requiring surgery, and pelvic fracture (Fig. 4) are among the most serious injuries seen. Actual uterine rupture (0.6 %) is almost always secondary to major trauma, with fetal demise approaching 100 % [2, 6]. A few survivors have been reported when surgery is performed immediately.

The radiological management of any woman of childbearing age being seen for an acute medical emergency must take into consideration the benefits of imaging in relation to the potential risks to a conceptus. We review here the general principles of how to develop the radiological workup of these patients, with special consideration to the traumatized patient. The importance of pre-

Fig. 1 a, b A 16-year-old comatose female patient after a motor vehicle accident. On arrival at the emergency room, there was no evidence of fetal viability of a 24-week pregnancy. CT of the head shows scattered bilateral frontal and parietal intracerebral bleeds. The patient also sustained right subcapsular and perirenal and left pararenal hematomas. There was intraperitoneal hemorrhage and pulmonary edema. Within 24 h, a spontaneous abortion occurred. Maternal demise occurred 8 days after admission

hospital management of the gravid patient, as well as the methods for providing for the welfare of her and her conceptus upon their arrival at the hospital and throughout their hospital stay, are discussed. Potential risks associated with fetal irradiation are also considered.

Initial considerations

While information on the reproductive status of any female patient is routinely acquired as part of her medical evaluation, such information is not needed before carrying out X-ray or CT evaluation of areas outside the abdomen and hips, as long as no direct irradiation of the conceptus is involved (Fig. 3). Such studies result in insignificant levels of radiation to the conceptus and may be performed without concern. Care should be taken to use proper collimation and to avoid inadvertent direct irradiation of the abdomen. The International Commission on Radiological Protection (ICRP) supports this concept [7]:

"When radiography of areas remote from the foetus is needed, such as, for example, the chest, skull or hand, these can be done safely at any time during pregnancy if proper collimation is used and if the equipment is properly shielded."

Radionuclide studies may directly irradiate the conceptus even though the organ system evaluated is remote from the conceptus. For example, in a lung perfusion study most of the ^{99m}Tc-macroaggregate albumin (MAA) is trapped in the lungs, but some will break down and recirculate, resulting in some direct irradiation to the conceptus. In a ventilation study of the lungs, xenon delivered through the airways will not pass into the blood to any significant extent, and so there will be less irradiation of the conceptus when this isotope is used. Even so, the dose to an early conceptus from these studies is not considerably greater than that from a CT study of the lung. The preferred study will depend primarily on the clinical circumstances (cooperation of the patient, gestation age, availability, etc.).

The evaluation of the reproductive status in women of childbearing age (defined as from the ages of 12 to 50 years) presenting with emergent abdominal symptoms is essential for radiological workup. The extent of the evaluation will depend on the patient's condition. In life-saving situations with a noncommunicative patient, a brief inquiry of a friend or relative as to whether the patient is known to be pregnant can be helpful. If she is pregnant, the radiologist will then know to avoid direct irradiation of the uterus, if possible. This knowledge may also aid in the interpretation of some radiographic findings (e.g. enlarged uterus).

In less serious circumstances, the X-ray request form should contain the date of the last menstrual period and the patient's response to the question, "Have you any reason to believe you might be pregnant?" Responsibility for obtaining this information can be assigned to the X-ray technologist, nurse, etc., as appropriate. However, in any given case the radiologist must determine whether the information is adequate. One should be especially sensitive to the minor who needs X-rays. It may be necessary to obtain information from these young patients

Fig. 2 a, b A 36-year-old woman in a rollover motor vehicle accident, 30-week pregnancy confirmed on nuclear medicine scan. CT of the cervical spine demonstrates a lateral mass fracture. The fetus was stable and the patient was ultimately transferred to another hospital after stabilization of her neck
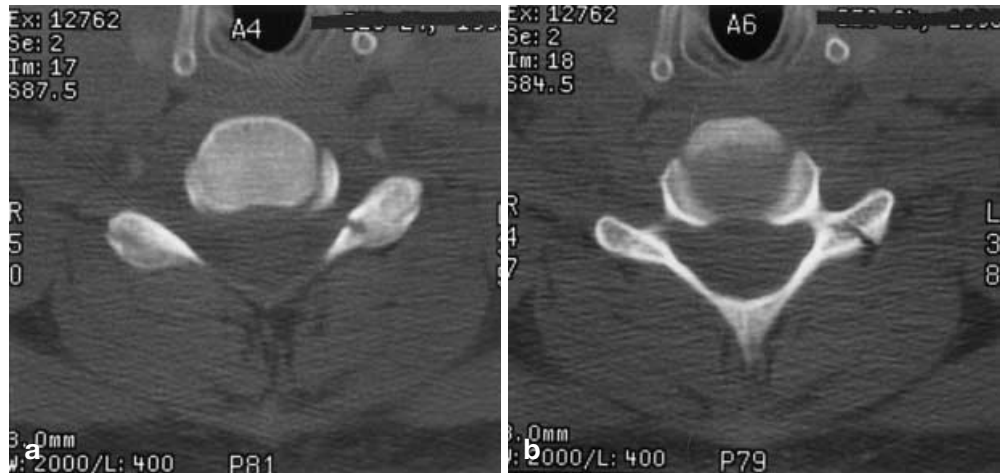
Fig. 3 A 32-year-old woman with 20-week-old fetus. Immediate chest film showed subcutaneous emphysema and a small right apical pneumothorax. The fetus was initially viable but a spontaneous abortion occurred the next day
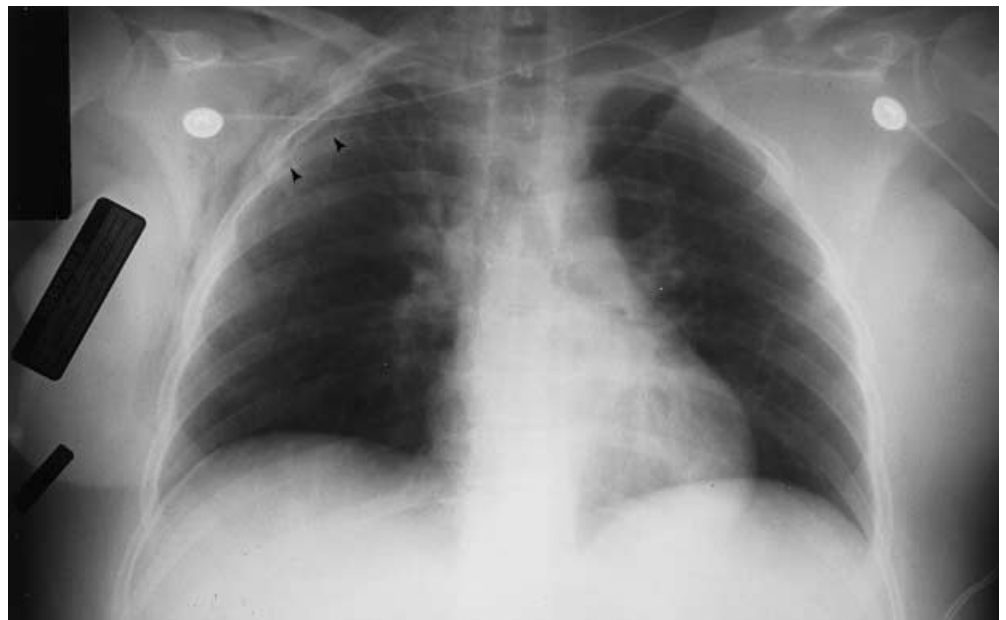
without the presence of their guardian (but with a female chaperone), since a minor may be reluctant to disclose that they are (or may be) pregnant.

If the patient's menstrual period occurred within the previous 4 weeks and there are no other indications that she is pregnant, radiological examination may proceed. It is important to be aware of the fact that the ICRP has developed a useful guideline that states the following [8, 9, 10]:

– "During the first 10 days following the onset of a menstrual period, there can be no risk to any conceptus, since no conception will have occurred. The risk to a child who had previously been irradiated in utero during the remainder of a 4-week period following the onset of menstruation is likely to be so small that there need be no special limitation on exposures required within these 4 weeks."

– " . . . exposure of the embryo in the first 3 weeks following conception is not likely to result in deterministic or stochastic effects in the liveborn child. A pregnant patient is likely to know, or at least suspect, that she is pregnant after one missed menstruation, so the necessary information on possible pregnancy can, and should, be obtained from the patient herself. If the most recent menstruation has been missed, and there is no other relevant information, the woman should be assumed to be pregnant."

If the resultant responses suggest that the patient could be pregnant, the radiologist must be notified and should consider the following [11]:

1. Could the patient's symptoms be the result of pregnancy?
2. Should a β-HCG serum test be ordered?

Fig. 4 Pelvic film of a 36-year-old in a motor vehicle accident with extended extraction from the automobile. On arrival at the hospital, the patient was undergoing an incomplete abortion with a retained placenta. Radiation to the fetus, therefore, was not of concern. Films show a fracture of the left femur and extensive foreign bodies overlying the pelvis from abrasions obtained at the time of the accident. The patient also sustained a fracture of the humerus, bilateral radial and ulnar fractures, a right patellar fracture, a scaphoid dislocation, and fractured maxillary sinus

3. How necessary is this procedure, taking into account the potential health consequences of not doing the study?
4. If the study is delayed, is it likely that it may become necessary later in the pregnancy when the conceptus may be at greater or lesser risk for radiation effects? (Different gestation ages are associated with different levels of concern, and delay may raise or reduce risks later.)

In the appropriate evaluation of acute healthcare problems in any female of childbearing age there are two golden rules for proper radiological management [11, 12]:

Golden rule 1: "When a woman requires an emergency radiological examination there should be no hesitation to do the study."

Golden rule 2: "If the study . . . indicated . . . requires direct exposure to the conceptus and there are no diagnostic alternatives, the radiologist should proceed and not hesitate to complete the procedure properly."

The ICRP [7] has issued a similar statement of guidance.

Trauma to the mother potentially affects the conceptus to a greater extent whether the trauma involves the abdomen or not. The following statements about the fetus in the maternal trauma must be considered:

1. The major cause of fetal death is the death of the mother [5].
2. The fetal death rate approaches 80 % in cases of maternal shock [13].
3. Complete or incomplete separation of the placenta is a major cause of fetal death (6–66 % and 30–80 %, respectively) [2].

It is important to stress that *fetal death can occur with either minor or major trauma* without any apparent correlation [2]. Thus, even such minor injuries as a small slip or fall can lead to fetal demise, usually due to incomplete or complete placental separation. To enhance fetal survival, therefore, pregnant females who have suffered even minor trauma must undergo some form of fetal monitoring, probably including fetal ultrasonography, for a period of time in the emergency room.

Prehospital management of the traumatized pregnant female

It is essential to transfer the pregnant patient to a trauma center with facilities for monitoring both mother and fetus. This is true even where injuries are only minor and even if the trauma seems to have affected only areas outside of the abdomen. While in transit the mother should be given oxygen. One must follow the "ABC" rules for monitoring the fetus (A airway, B breathing, C circulation) and keep the mother in the left lateral decubitus position to prevent blockage of venous return through the inferior vena cava. The receiving hospital should be continually updated with mother/fetus data via telemetry, and the appropriate hospital staff should be assembled, which variously will include a neonatologist, a perinatologist, a trauma surgeon, a sonographer, a staff radiologist, and possibly an angiographer (in cases of pelvic fracture, bleeding, etc.).
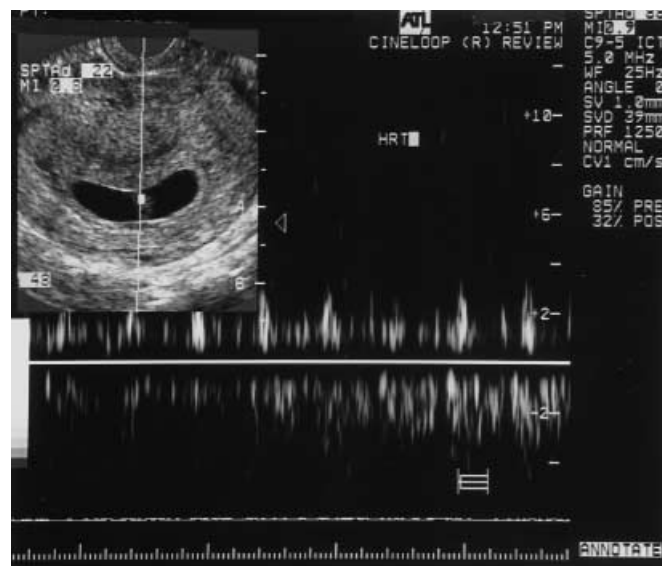
Management upon arrival at the hospital

When signs and symptoms of an acute abdomen are found, the patient must be immediately assessed for acute surgical emergency. Maternal hypotension is especially worrisome since this also affects the fetus. Liver and spleen lacerations occur closer to term because of compression by the rib cage [13]. Bladder trauma becomes more significant from 12 weeks after conception due to displacement of the bladder by the uterus. As gestational age progresses, bleeding secondary to increased uterine flow and pelvic/venous engorgement are additional concerns [6].

Since fetal demise can occur in cases of both major and minor trauma, the pregnant female should be monitored in the emergency room for at least a few hours after even minor trauma. With major trauma, the patient should be hospitalized and monitored for at least 24 h [13, 14, 15]. Upon arrival, the mother should first be stabilized. A pertinent prenatal history should be obtained [2], including information as to whether the mother has currently noted fetal motion. Pertinent initial films might include a portable chest film (Fig. 3), an abdominal film, and a lateral cervical spine film. If a perforated viscus is suspected, a left lateral decubitus image of the abdomen should be obtained. Careful collimation and pelvic shielding should be used whenever possible. The fetus should then be evaluated with ultrasound to look for motion, breathing, heart rate, and abruptio placentae [16, 17] (Figs. 5, 6). If these are unremarkable, the same ultrasound unit can be used to rapidly screen the maternal liver, kidney, and spleen for injury. Doppler should be used to check for peritoneal fluid and look for maternal renal blood flow. CT has been suggested as the next rapid technique, especially if readily available in the emergency room [18].

In the benefit/risk analysis of diagnostic radiation exposure, the following should be considered [11, 19]:

1. In all stages of pregnancy there is, at best, only a slight possibility of induced carcinogenesis (e.g., roughly 0.2–0.8 % for a pelvic CT delivering a 50 mGy dose to the conceptus) [20].
2. There is a slight possibility of fetal demise during the first 2 weeks after conception secondary to diagnostic radiation exposure, but with a risk of less than 1.0 % [21].
3. There is a potential risk of small head size with exposure 2–15 weeks after conception, but intellectual damage has not been demonstrated for the 8 weeks after conception. Furthermore, the degree of the decreased head size is not easily recognized, except in population studies [22].
4. The risk of malformation exists for weeks 2–15 after conception, but with diagnostic radiology it appears to be very small because it probably has a threshold of more than 100 mGy [11]. Properly performed radiological studies expose the conceptus to only low-dose radiation. Typically, diagnostic plain films expose the conceptus of a pregnant female to less than 10 mGy [11].
5. The principal concern is when multiple higher-dose examinations involving the uterus (CT, angiography, etc.) are required. Typical abdominal studies and abdominal fluoroscopy lead to doses of about 1–50 mGy [11].
6. Information as to doses given in angiography, the use of coned-down techniques, and careful attention to minimizing fluoroscopy time are all necessary to keep below the threshold of concern (< 50 mGy).

Fig. 5 A 21-year-old pregnant woman in early pregnancy with interventricular hemorrhage. Pulsed Doppler shows a viable fetus
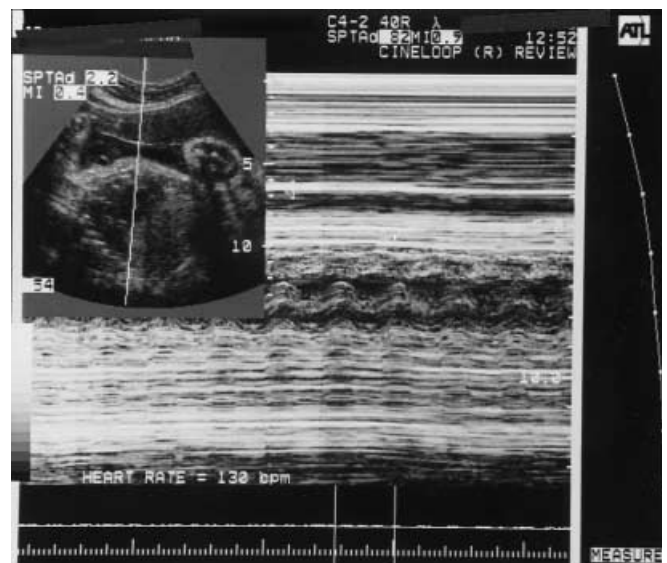
Fig. 6 A 36-year-old woman who sustained an acetabular fracture. Fetal ultrasonography showed a viable fetus with a heart rate of 130-beats/min

7. CT, when properly performed using modern equipment, should be reasonably safe. Pelvic CT usually results in an exposure of 20–50 mGy. Doses for typical protocols should be evaluated periodically to establish doses from particular scanners. For example, doses from multislice helical techniques may be quite different from those of conventional step-and-scan techniques. The dose from CT becomes a more important issue when multiple passes through the conceptus are involved.

8. Careful consideration should be made as to possible alternative imaging techniques, or appropriate modifications of the already selected study should be made to lessen the fetal radiation dose.

9. The effect of contrast agents on the fetus is unknown, but no harm has been demonstrated in rats or rabbits.

Monitoring radiation exposure to the conceptus is an essential element of patient care. As a minimum, the technique factors of radiological evaluation (kVp, mAs, fluoroscopy on-time, machine identification, etc.) should be recorded. A thermoluminescent dosimeter, if available, or a personal radiation monitor in some cases, will provide a direct reading of the radiation exposure.

Follow-up after initial emergency room workup

If the mother leaves the emergency room, appropriate personnel must accompany her to other areas (e.g., X-ray, etc.). She should be monitored at all times. The mother should be kept in the left decubitus position during the third trimester to prevent vena caval obstruction [2]. If fetal bradycardia develops (heart rate < 110 min), an immediate cesarean section should be performed [2].

In determining what diagnostic tests to perform and when, the following should be considered [12]:

1. Diagnostic peritoneal lavage has a high sensitivity for hemoperitoneum, but is not organ-specific.
2. CT is an excellent rapid screening test if it is readily available. It is also more sensitive in diagnosing injuries affecting certain organs (i.e., liver, pancreas; Fig. 7). A recent study by Lowdermilk et al. [18] suggests that poor perfusion of the placenta on spiral CT may prognosticate poor fetal outcome (Fig. 8).
3. Ultrasound can be used if there are appropriate personnel present and for select problems, e.g., presence of peritoneal fluid or a rapidly deteriorating clinical situation. However, its sensitivity for some injuries (pancreas, kidney) is significantly less than that of CT.
4. MRI, if available and the patient is reasonably stable, is an excellent modality, especially for suspected neural injuries in the mother.
5. Angiography may be needed for active bleeding and embolization in life-threatening situations. The most skilled operator using as little fluoroscopy as is safely possible should perform this test.
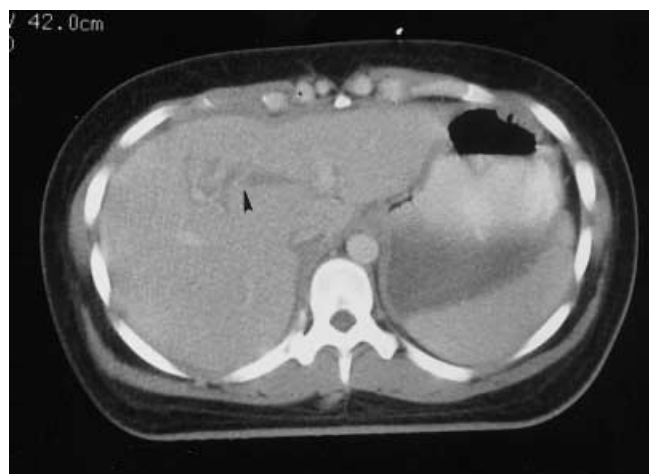

Fig. 7 A 24-year-old woman in a motor vehicle accident. CT showed a non-life-threatening liver laceration *(arrowhead)*

Fig. 8 A pregnant woman in a high-speed motor vehicle accident. CT through the placenta showed significant hypodensity to the lateral aspect of the placenta *(arrowheads)*. This lack of perfusion to a significant portion of the placenta may portend a poor fetal prognosis. A nonviable fetus was delivered 3 days after injury

In cases of upper quadrant and mid-abdomen injury, ultrasound or MRI might be the first modalities considered, due to their nonionizing nature. However, the role of MRI in this setting has not been well investigated, and motion compromises its utility. If MRI is employed, Shellock and Kanal recommend that contrast should be avoided [23]. For conventional CT of the upper abdomen, we suggest 10-mm cuts after administration of oral and intravenous contrast [12]. If helical CT is available, we recommend a pitch of 1.0 and a 7-mm beam width. In appropriate cases, a higher pitch of 1.5
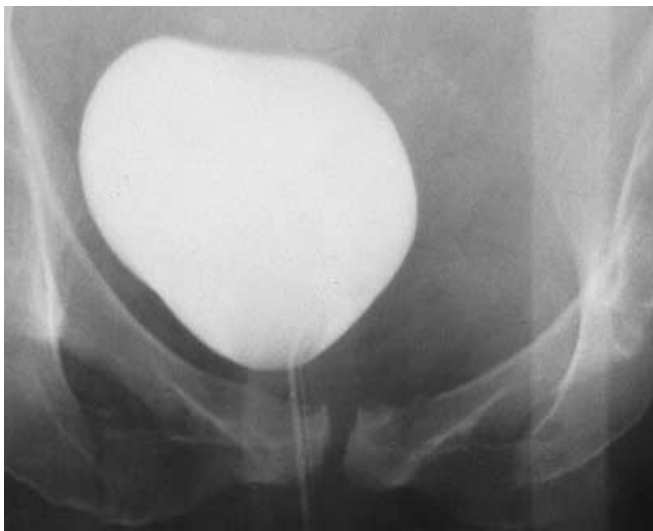
Fig. 9 A 32-year-old pregnant woman with hematuria and pubic rami fractures after a motor vehicle accident. A single film cystogram showed no bladder injury. A 3-week-old, initially viable fetus was aborted 1 day later

or 2 can be used. For CT of the mid abdomen in early pregnancy, when the conceptus will not be directly irradiated, we suggest either nephrographic or corticomedullary phase filming followed by delayed imaging to exclude active bleeding. For later stages of pregnancy, we suggest late phase imaging only with the same technique. Pelvic evaluation is done for investigation of peritoneal fluid or skeletal injuries. If CT of the pelvis is required, we suggest 7-mm cuts at a pitch of 1.5–1.8. If skeletal films suggest performing an evaluation of complex bony injury by CT, the technique will be governed by the imaging detail required, but the examination should be confined to the appropriate area of interest.

In evaluating the urinary tract, microscopic hematuria, without accompanying signs of a major injury, is usually benign and may require no further workup unless a renal artery, renal vein, or ureteric injury is suspected. Patients with gross hematuria and a pelvic fracture are at risk for bladder rupture and require a cystogram (Fig. 9) (a CT cystogram is not the preferred technique in pregnancy due to the increased radiation dose to the conceptus). For the cystogram the bladder should be filled with at least 300–350 ml contrast before an anteroposterior abdominal film is performed. The bladder should be drained by catheter and an additional film should be obtained [12]. If these films are not diagnostic, oblique views might be considered. In cases of suspected kidney injury alone, a single film intravenous pyelogram may be adequate (Fig. 10). If unilateral nonfunction is seen or the intravenous pyelogram is nondiagnostic, CT is appropriate to diagnose renal artery thrombosis or a potential major renal injury. Patients with gross hematuria and hypotension or signs of major injury involving another

Fig. 10 A 19-year-old pregnant woman with hematuria after trauma. Intravenous pyelogram showed normal upper tract and a third-trimester pregnancy

organ system should be examined by CT so that the intraperitoneal organs as well as the kidneys can be evaluated [24].

Summary

This article has reviewed the general principles in deciding whether and when radiation exposure is appropriate in a childbearing female with an acute medical problem. In acute trauma, the primary consideration is saving maternal life, without which fetal demise is inevitable. Most important, fetal and maternal monitoring must be continuous, whether the trauma is minor or major. Key is the recognition that radiation exposure should be considered in the management of the traumatized female patient, but an expeditious, correct diagnosis is the most important issue. *Deleterious radiation effects never outweigh the considerations of fetal and maternal survival.*

References

1. Doan-Wiggins L (1990) Trauma in pregnancy. In: Harwood-Nuss A (ed) Obstetric emergencies. Churchill Livingston, New York, pp 45–64
2. Doan-Wiggins L (1994) Trauma in pregnancy. In: Benrubi GI (ed) Obstetrics and gynecologic emergencies. Lippincott, Philadelphia, pp 57–76
3. Lavin JP Jr, Polsky SS (1983) Abdominal trauma during pregnancy. Clin Perinatol 10:423–438
4. Pepperell RJ, Rubinstein E, MacIsaac IA (1977) Motor-car accidents during pregnancy. Med J Aust 1:203–205
5. Rothenberger D, Quattlebaum FW, Perry JF, Zabel J, Fischer RP (1978) Blunt maternal trauma: a review of 103 cases. J Trauma 18:173–178
6. Pearlman MD, Tintinalli JE, Lorenz RP (1990) Blunt trauma during pregnancy. N Engl J Med 323:1609–1613
7. ICRP (International Commission on Radiological Protection) (1982) Protection of the Patient in Diagnostic Radiology. (ICRP publication 34) Pergamon Press, Oxford
8. ICRP (International Commission on Radiological Protection) (1987) Recommendations of the ICRP. (ICRP publication 26) Pergamon Press, Oxford
9. ICRP (International Commission on Radiological Protection) (1991) Recommendations of the International Commission on Radiological Protection. (ICRP publication 60) Pergamon Press, Oxford
10. ICRP (International Commission on Radiological Protection) (1993) Summary of the current ICRP principles for protection of the patient in nuclear medicine. Pergamon Press, Oxford
11. Wagner LK, Lester RG, Saldana LR (1997) Exposure of the pregnant patient to diagnostic radiation: a guide to medical management, 2nd edn. Medical Physics, Madison, Wis
12. Goldman SM, Wagner LK (1996) Radiologic management of abdominal trauma in pregnancy. AJR Am J Roentgenol 166:763–767
13. Milos MJ (1990) Obstetric and gynecologic trauma. In: McCort JJ, Mindelzum RE (eds) Trauma radiology. Churchill Livingston, New York, pp 231–239
14. Haycock CE (1985) Blunt trauma in pregnancy. In: Haycock CE (ed) Trauma and pregnancy. PSG Publishing, Littleton, Mass, pp 34–43
15. Esposito TJ, Gens DR, Gerber-Smith L, Scorpio R (1989) Evaluation of blunt trauma occurring during pregnancy. J Trauma 29:1628–1632
16. Lavery JP (1992) Management of moderate to severe trauma in pregnancy. Antepartum Gen Obstet Emerg 22:69–90
17. Smith AJ, LeMire WA, Hurd WW, Pearlman M (1994) Repair of the traumatically ruptured gravid uterus: a report of two cases resulting in viable pregnancies. J Reprod Med 39:825–828
18. Lowdermilk C, Gavant ML, Qaisi W, West OC, Goldman SM (1998) Blunt traumatic injury in the pregnant patient: role of imaging in maternal and fetal survival. Radiology 209:258–259
19. Goldman SM, Wagner LK (1999) The radiological ABCs of maternal/fetal survival after trauma – where minutes may count. Radiographics 19: 1349–1357
20. BEIR (Committee on the Biological Effects of Ionizing Radiations) (1980) The effects on populations of exposure to low levels of ionizing radiations. National Academy Press, Washington, DC
21. Stovall M, Blackwell CR, Novada DH, et al (1995) Fetal dose from radiotherapy with photon beams: report of AAPM Radiation Therapy Committee Task Group no. 36. Med Phys 22:63–82
22. Otake M, Schull WJ (1992) Radiation-related small head sizes among prenatally exposed survivors. Int J Radiat Biol 63:255–270
23. Shellock FG, Kanal E (1994) Magnetic resonance bioeffects, safety, and patient management. Raven, New York
24. Trunkey DD, Hill AC, Schecter WP (1991) Abdominal trauma and indications for celiotomy. In: Moore EE, Mattox KL, Feliciano DV (eds) Trauma, 2nd edn. Appleton Lange, Norwalk, Conn, pp 409–426