CME

Imaging During Pregnancy

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The use of imaging techniques in women who are pregnant has increased greatly over the past decade. This focused review discusses the risks and indications of ultrasonography, magnetic resonance imaging, computed tomographic scanning, and fluoroscopy for the evaluation of the parturient with non-obstetric disorders. Diagnostic imaging of the pregnant woman for the evaluation of disorders not related to pregnancy is evolving, and protocols will vary from institution to institution. The potential benefit from indicated diagnostic radiological procedures in the parturient nearly always outweighs risk to the fetus because radiation exposure from a single procedure conveys little fetal risk. (Anesth Analg 2010;110:863–7)

The use of computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography is increasing in women who are pregnant. A 10-year review of radiological examinations in pregnant women from 1997 to 2006 reported a 121% increase in the use of imaging tests requiring ionizing radiation.[1] Routine ultrasound screening of the fetus remains controversial because it does not improve perinatal morbidity,[2,3] despite an 80% detection rate of fetal anomalies at experienced centers.[4] Ultrasonography is the initial screening test for the evaluation of maternal trauma to the abdomen during pregnancy, although concerns over sensitivity often necessitate further examination with CT and MRI.[5] Ultrasonography significantly aids in the evaluation of placental abnormalities and blood flow.[6,7] Both CT and MRI are useful in the evaluation of suspected maternal pulmonary embolism and central nervous system, chest, pelvic, and intraabdominal disorders.[5] Although indications for single diagnostic CT and MRI procedures are not significantly altered during pregnancy because the radiation dose does not threaten the well being of the fetus (Fig. 1),[8] care of the parturient during radiological procedures should include proper patient positioning to minimize aortocaval compression and consideration of the potential for maternal pulmonary aspiration, particularly in parturients with trauma or those receiving conscious sedation.

Historically, radiation exposure was measured in terms of the number of ions produced per kilogram of air (roentgen units). Currently, absorbed dose (units of rads [rad] or gray [Gy]; 1 Gy = 100 rad) is used to report the amount of energy imparted by radiation per mass of tissue for a given procedure.[9] Radiation exposure during a given procedure is typically measured using air-filled ionization chambers, and the absorbed dose is calculated using roentgen to rad conversion factors. The conversion factor is approximately 1 for soft tissue in the energy ranges used in radiological examinations.[9] The extent of biological damage caused by any given radiation exposure depends on the exposed organ system(s). The relative effective dose, measured in roentgen equivalents (rem) or sievert (Sv; 1 Sv = 100 rem), measures the amount of energy delivered based on absorbed dose and the effectiveness of a particular type of radiation in inflicting biological damage.[9]

The method of estimating radiation dose varies depending on the examination. For example, radiation dose estimates for chest radiography are derived from surface exposure measurements, whereas the multiple scan average dose, the average dose delivered to tissue resulting from a given CT scan, is used to estimate CT radiation dose.[9] The multiple scan average dose can be measured directly by placing a dosimeter in a scanner and averaging results from multiple scans, but is typically estimated from the CT dose index, the estimated absorbed dose from a single CT scan.[10] Pencil ionization chambers placed in Lucite models (phantoms) are used to measure the amount of radiation exposure directed at a given CT slice and scattered exposure from radiation directed at adjacent slices.[9] Maternal estimated absorbed doses for a CT procedure are then based on how many slices are irradiated.[9] Fetal absorbed dose for a scan is estimated from the number and spacing of image slices and whether the uterus is in the field of exposure.[11] Because these methods may misestimate fetal doses by as much as 100%, investigators have suggested that computer-generated models of maternal and fetal anatomy subjected to CT scanning using Monte Carlo techniques may provide better estimates of absorbed maternal and fetal dose.[12]

ULTRASONOGRAPHY

Maternal Applications

Transabdominal ultrasound is the first imaging test that should be used in the evaluation of suspected maternal intraabdominal pathology because it does not expose mother or fetus to ionizing radiation. Acute appendicitis affects 1 of 1500 pregnancies and is the most common non-obstetric surgical emergency.[13] Ultrasonography was shown to be 100% sensitive, 96% specific, and to have a 94% positive predictive value in 1 older study[14]; however, the use of ultrasound for this application is limited by operator skill and maternal obesity,[15] and recent work suggests that nonvisualization rates after the second trimester may be as

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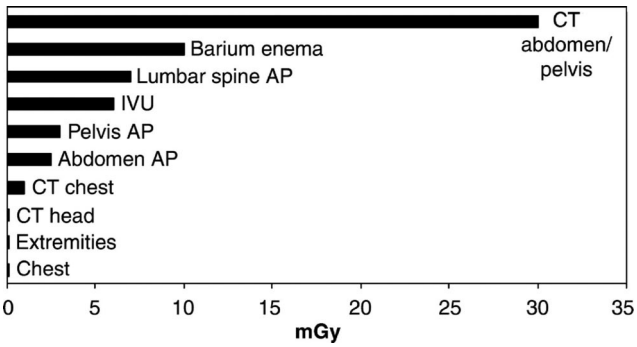

Figure 1. Fetal absorbed doses from head computed tomography (CT), extremity radiography, and chest radiography are <0.1 mGy. mGy = milligray; AP = anteroposterior; IVU = IV urography. (Reproduced from Ref. 15, with permission.)

high as 90%.[16] CT or MRI will therefore be indicated for many nondiagnostic cases.[5,17]

Trauma affects 6% to 7% of all pregnancies.[18] Although a specificity of 100% for the diagnosis of intraabdominal organ damage was cited in 1 large review of ultrasound use in blunt trauma in the pregnant patient,[19] a wide range of reported sensitivities (61%–83%) was noted in another review.[15] In addition, some authors recommend that supplemental CT scanning be performed if ultrasonography suggests visceral injury.[19] Therefore, CT will most often be used for the evaluation of the parturient with blunt trauma. A rapid fetal survey using ultrasonography to assess heart rate and to evaluate placental position and abnormalities should be performed.[17]

Nephrolithiasis complicates 1 in 3300 pregnancies, and ultrasonography showed a sensitivity of stone visualization of 60% in 1 small study.[20] CT or IV urography (IVU) is indicated after nondiagnostic ultrasound studies.[21]

The use of transvaginal ultrasound and rapid tests for serum human chorionic gonadotropin have markedly reduced death rates from hemorrhage associated with ectopic pregnancy and allow adoption of expectant management strategies.[22] Transvaginal ultrasonography identifies adnexal masses associated with ectopic pregnancy with a single-scan sensitivity and specificity of 75% and 99%, respectively.[23]

Placental Assessment

Transvaginal ultrasonography is effective for determining placental location. Ultrasonography is nearly 100% sensitive and specific for the diagnosis of placenta previa in the setting of painless vaginal bleeding[24] and aids in the diagnosis of placenta accreta in women with previa and a history of low transverse cesarean delivery.[25,26] Characteristic ultrasound findings include irregularly shaped placental lacunae (vascular spaces) within the placenta, loss of the retroplacental "clear space," and protrusion of the placenta into the bladder.[27] The presence of lacunae at 20 weeks' gestation and obliteration of the clear space are associated with a 90% and 85% positive predictive value for placenta accreta, respectively.[27]

Ultrasonography is less helpful in confirming the diagnosis of placental abruption, with a sensitivity of only 50% in women with clinical evidence of abruption at delivery.[6] Subchorionic or retroplacental hemorrhage is often not visualized on ultrasonography in patients with clinical signs and symptoms suggestive of placental abruption.[28]

Ultrasound for Neuraxial Anesthesia

Ultrasound-guided placement of epidural catheters using low-frequency (2- to 5-MHz) probes has been described with proponents citing improved identification of the specific interspinous space,[29,30] good precision in identifying depth of the epidural space from the skin,[31] particularly in obese parturients,[32] and reduction in the need for needle repositioning during identification of the epidural space.[33] Positioning of the ultrasound probe transverse to the long axis of the spine seems to have the most clinical usefulness, with placement along the long axis of the spine (longitudinal approach) helpful in confirming interspace level.[31] Studies evaluating whether ultrasound guidance will reduce the incidence of accidental dural puncture have not been done.

Ultrasound Safety

In the 40 years since introduction into clinical practice, ultrasonography has not been shown to convey any significant health risk to the fetus or mother,[34] although most safety data were collected before 1992 when the permissible power output of scanners was significantly lower than the power used in contemporary scanners.[35] Tissue temperature increases would not be expected to exceed 0.5°C for even prolonged examinations with use of modern scanners and therefore are unlikely to have significant adverse effects.[34] However, the American College of Obstetricians and Gynecologists states that casual use of ultrasound without medical indication is inappropriate and the lowest possible ultrasound exposure setting should be used to gain the necessary diagnostic information.[4]

MAGNETIC RESONANCE IMAGING

Maternal Applications

Although interest in the use of MRI for the diagnosis of appendicitis has increased, its relative effectiveness compared with ultrasonography is not clear. One study of 51 patients noted a sensitivity of 100% and a specificity of 93.6%,[36] but the diagnostic effectiveness of MRI, similar to ultrasonography and CT, is limited in late gestation when the appendix will not be visualized between 17% and 52% of the time.[16,17] Little data on the use of MRI for the diagnosis of renal colic are available, but 20% of academic radiologists would use it instead of CT.[37] MRI does not seem to be a practical option for rapid evaluation of maternal trauma, with fewer than 5% of academic radiologists finding it useful.[37] MRI has been described for the assessment of cephalopelvic disproportion,[38] but some authors conclude that CT pelvimetry is a better option.[17] MRI may improve the diagnosis of placenta accreta in the presence of placenta previa, but ultrasonography is the primary diagnostic tool,[6,24–26] although MRI with contrast may be helpful in refining the surgical management of cesarean hysterectomy.[39,40] MRI can aid in the diagnosis of ectopic pregnancy when ultrasound findings are equivocal but adds little when ultrasonography is diagnostic.[41]

Table 1. Effects of Postconceptional Age and Radiation Dose on Radiation-Induced Teratogenesis

Postconceptional age	Effects	Estimated threshold dose[a]
Period postconception		
0–2 wk (before implantation)	Death of embryo or no consequence (all or none)	50–00 mGy
2–8 wk (period of organogenesis)	Congenital anomalies (skeleton, eyes, genitals)	200 mGy
Fetal period		
8–15 wk	Severe mental retardation (high risk)[b]	60–10 Gy
	Intellectual deficit	25 IQ point loss per Gray
	Microcephaly	200 mGy
16–25 wk	Severe mental retardation (low risk)	250–80 mGy

Adapted from Ref. 15, with permission.
mGy = miligray.
[a] Estimated dose at which risk begins to increase from baseline. Data based on results of animal studies, epidemiologic studies of survivors of the atomic bombings in Japan, and studies of groups exposed to radiation for medical reasons (e.g., radiation therapy for carcinoma of the uterus).
[b] Period of rapid neuronal development and migration.

MRI Safety

Fetal teratogenicity and acoustic damage are the main concerns with MRI use during pregnancy, although several studies in laboratory rodents[42,43] and in children up to 9 years of age exposed to MRI in utero at 1.5 T have failed to show adverse teratogenetic, behavioral, or hearing effects[44,45]; however, the safety of MRI at 3 T has not been studied.[41] Although most radiologists would avoid the use of MRI in the first trimester of pregnancy, most authors state that it is preferable to any study involving ionizing radiation.[41] Studies demonstrating fetal harm when gadolinium (Food and Drug Administration category C drug) is used for contrast are lacking in humans, but most radiologists avoid its routine use during pregnancy.[15] After maternal administration, gadolinium appears rapidly in the fetal bladder and then is excreted into the amniotic fluid where it can be potentially swallowed by the fetus and absorbed from the fetal gastrointestinal tract.[41] The fetal half-life is therefore unknown with prolonged fetal exposure possible.[41] Fortunately, most maternal pelvic and fetal MRI does not require its use, although it may allow better assessment of the placental/myometrial interface in cases of suspected placenta accreta.[41]

COMPUTED TOMOGRAPHY

Maternal Applications

The rate of pregnancy-associated pulmonary embolism is 1 to 2 per 7000 pregnancies, usually occurring postpartum and in association with cesarean delivery, maternal thrombophilias, and preeclampsia.[46] CT pulmonary angiography exposes the parturient to less radiation and has a better positive and negative predictive value than ventilation-perfusion scintigraphy. A meta-analysis of 12 studies suggests that helical CT scanning has a sensitivity of 86% and specificity of 93.7% in a general, nonpregnant population.[47]

In assessing the parturient with trauma, CT is almost always indicated when clinical or ultrasound findings suggest visceral injury without hemorrhage and for injuries of chest, mediastinum, aorta, retroperitoneum, bowel, bladder, or bones.[48] Noncontrast CT imaging or IVU may be required for the evaluation of renal colic in the pregnant patient with a negative ultrasound study. CT has replaced IVU because it is sensitive and specific and avoids contrast administration, but some authors prefer intravenous urography (IVU) in parturients because of its lower radiation exposure.[21] A few published studies suggest that CT significantly improves the rate of false-positive inflamed appendices when ultrasound findings are equivocal.[49] As noted above, the interpretation of all imaging modalities becomes problematic in the third trimester.[17] The use of CT for fetal evaluation is not indicated.

CT Safety

A survey of Canadian obstetricians and family practitioners showed that 5% to 6% would recommend termination of pregnancy after abdominal CT scanning in early pregnancy,[50] despite data that show little increased risk for fetal teratogenicity, childhood cancer, and abortion.[15] Clinical studies have failed to show an increase in the incidence of fetal malformations[17] because the estimated dose of a single CT pelvic scan during the first trimester (0.024–0.30 Gy; 2.4–3.0 rad) is lower than the dose threshold at which risk significantly increases (Table 1).[15] The use of multiphase CT studies is associated with increased fetal exposure,[51] as is multiple repeat scans, so the risks associated with its use should be weighed in light of the anticipated benefits.[15] CT scanning of maternal head and chest is associated with negligible fetal exposure.[15] There is an increased risk of spontaneous abortion if the radiation dose exceeds 0.1 Gy (10 rads) within the first 2 weeks after conception, but there does not seem to be an increased risk thereafter.[52] A single maternal pelvic CT scan may increase the risk of childhood cancers in the exposed fetus by a factor of 2; however, because the baseline risk is 1 in 2000, the increase in absolute risk is very low but may be higher for exposure during the first trimester.[17] The American College of Obstetricians and Gynecologists does not recommend abortion for concern of childhood cancers after maternal pelvic CT examination.[8] Iodinated contrast media (Food and Drug Administration category B drug) does not convey fetal risk for teratogenesis in animal studies but has not been studied in humans, although the risk should be assumed to be small.[8] Although the depression of fetal thyroid function is possible, there are no studies that have assessed the effects.[15]

FLUOROSCOPY

Unlike CT and radiography where nonabdominal exposure exposes the fetus to negligible risk, fluoroscopy might be expected to convey significant risk regardless of the examined site because of prolonged exposure times and use in

cases of unsuspected pregnancy.[53] Techniques to be used in women of childbearing years include proper uterine shielding for nonpelvic procedures, minimization of beam-on time, collimation to minimize beam width and exposure area, reduced image magnification, selection of appropriate radiation output, and equipment that uses pulsed fluoroscopy and last image hold.[54,55] Studies estimating fetal exposure should be reassuring to both practitioner and patient because radiation exposure has been estimated to be minimal for cardiac ablation procedures,[56] intraoperative hip fluoroscopy,[57] endoscopic retrograde cholangiopancreatography,[58] and for spinal procedures during which the uterus is out of the radiation beam, although an estimated dose of 105 mGy might be delivered for uterine exposures lasting 35 minutes.[53] Ultrasound-guided techniques for the diagnosis of pancreatic disease,[59] verification of correct needle placement during neural blockade for pain control,[60,61] and treatment of facet joint pain[62] have been recently described and may offer alternatives to fluoroscopically guided treatments.

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