26 Acute Abdominal Pain in Pregnant Patients: Evidence-Based Emergency Imaging

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Key Points

Imaging in pregnancy must focus on safe and efficient diagnosis of abnormalities in the mother while taking into account fetal well-being, especially exposure to ionizing radiation and intravenous contrast agents.

- Symptoms and clinical findings of appendicitis, cholecystitis, pyelonephritis, and other acute abdominal conditions are not always typical on physical exam during pregnancy. However, maternal and fetal morbidity is often higher, especially if there is delay in diagnosis.
- Most imaging pathways in acute abdominal pain during pregnancy start with sonographic evaluation, but when sonography is equivocal, MRI or CT can be considered second line depending on the pre-test probability (moderate evidence).
- Fetal MRI is safe at 3.0 Tesla or less during second and third trimesters (moderate evidence).
- The use of MRI in first trimester should be restricted to maternal indications for which information provided is clinically important (limited evidence).

List of Abbreviations

ACOG	American Congress of Obstetricians and Gynecologists
ACR	American College of Radiology
ALARA	As low as reasonably achievable
CT	Computed tomography
LLQ	Left lower quadrant
LUQ	Left upper quadrant
MRI	Magnetic resonance imaging
NPV	Negative predictive value
OB/GYN	Obstetrics and gynecology
PPV	Positive predictive value
RLQ	Right lower quadrant
RUQ	Right upper quadrant
SAR	Specific absorption rate
SOGC	Society of Obstetricians and Gynecologists
US	Ultrasound

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Definitions and Pathophysiology

Imaging of patients with acute abdomen during pregnancy presents many challenges. In pregnancy, there are many physiologic changes that occur and become more pronounced as the pregnancy progresses. Intra-abdominal organs may be displaced from their usual position, and physiologic changes associated with pregnancy can mimic pathology in some cases. Also, clinical symptoms at presentation may be atypical, leading to delays in diagnosis.

Epidemiology

Throughout pregnancy, an acute abdomen can be due to obstetric and gynecologic (OB/GYN) causes, or it can be non-OB/GYN causes. Non-OB/GYN acute abdomen presents in approximately 1 in 500–630 pregnancies [1]. Diagnosing these causes of acute abdomen in pregnant women can be challenging because the clinical presentation can be atypical or confusing, at times mimicking normal symptoms of pregnancy. Radiologic evaluation may be necessary, but safety issues such as ionizing radiation to the mother and fetus must be considered.

Overall Cost to Society

As an imaging modality in pregnant patients with acute abdominal pain, sonography is inexpensive compared to MRI and also incrementally less than CT. Sonography is less expensive but has known diagnostic limitations and may perform poorly depending on the pregnant body habitus. The cost of delayed diagnosis includes maternal and fetal morbidity and mortality including increased length of stay in hospital [2]. MRI and CT may provide a more definitive diagnosis, but are more expensive and associated with risks to the mother and fetus, including radiation (CT) and intravenous contrast (MRI and CT).

The exact risk of fetal radiation exposure is unclear and likely depends on dose as well as the stage of development during pregnancy when exposure occurs. It is estimated that a 10–20 mSv fetal exposure may increase the risk of leukemia by 1 in 2000 children exposed to radiation in utero [3]. The background risk of developing this disease is 1 in 3000. Although this can be expressed as a 1.5- to 2.0-fold increased risk of developing cancer, the cost of aborting all fetuses exposed to ionizing radiation would mean that one case of leukemia would be prevented for 1999 normal fetuses aborted [3].

Goals of Imaging

Imaging in pregnancy focuses on timely diagnosis of clinically significant abdominal and pelvic pathology. Efforts are directed at optimizing maternal outcomes, as the best chance for fetal survival is maternal survival.

The ALARA (as low as reasonably achievable) principle should be followed when considering optimal imaging for pregnant patients. Most imaging algorithms for assessing pregnant patients begin with ultrasound, due to a combination of lack of ionizing radiation, fairly ubiquitous imaging access, lower cost, and generally adequate sensitivity and specificity for diagnosing most common acute abdominal abnormalities in pregnancy. However in equivocal cases or when symptoms are discordant, MRI or CT scan should be considered for further evaluation [4].

According to the 2014 SOGC practice guidelines, the use of MRI in first trimester should be restricted to maternal indications for which the information is considered clinically imperative. Of note, exposure to unenhanced, magnetic resonance imaging during the first trimester has not been associated with any long-term sequelae (SOGC level of evidence III-C, limited evidence) (Fig. 26.1) [5]. During the second and third trimesters, fetal magnetic resonance imaging is safe

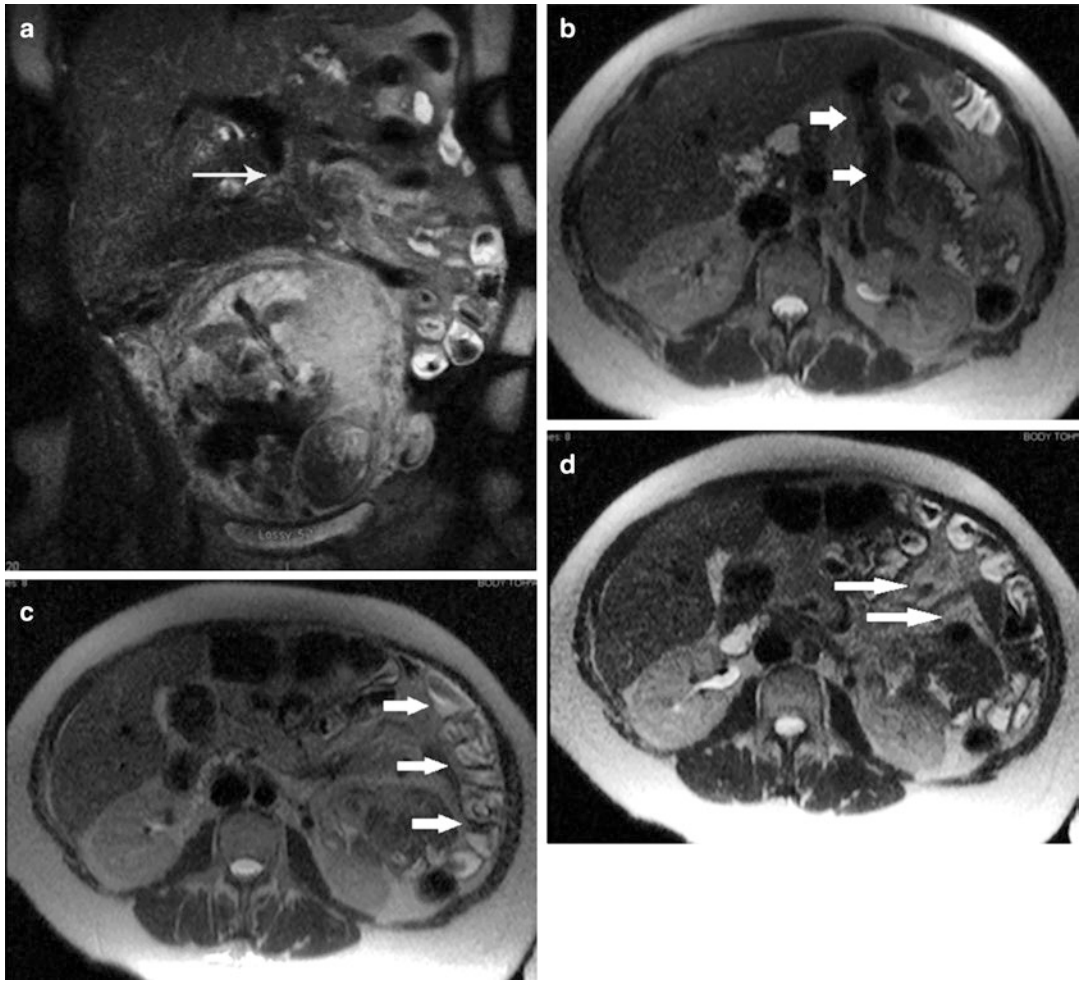

Fig. 26.1 (**a**)–(**d**). 29 year old presenting to the emergency department with intermittent, worsening abdominal pain. She had a history of Roux en Y gastric bypass for weight loss 2 years earlier and had achieved significant weight loss prior to pregnancy. MRI was performed without intravenous contrast demonstrating an internal hernia. Note the beak sign of SMV as it gets twisted (*arrow in a*). There is an unusual loop of bowel travelling anterior to posterior (*arrowheads in b*). Too many bowel loops on left (*arrows on image c*) and there is slight edema in the small bowel mesentery (*small arrows in d*)

up to 3.0 Tesla (SOGC level of evidence II-2, moderate evidence) (Fig. 26.1) [5].

Methodology

"Acute abdominal pain in the pregnant patient." A literature search was performed of English language articles from 2005 to February 2015, using the MEDLINE database as well as EMBASE and the Cochrane Library. Search terms included the various MeSH terms including diagnostic imaging, appendicitis, bowel obstruction, renal calculi, renal colic, pyelonephritis, gallstones, ectopic pregnancy, abruption, safety, and ovarian torsion combined with the term pregnancy, as well as the MeSH terms computed tomography, ultrasound, sonography, MRCP, and magnetic resonance imaging. Inclusion criteria incorporated systematic reviews, meta-analysis, prospective studies, and retrospective studies related to acute abdomen in pregnancy. Review articles and society position papers related to staging systems on these topics were also sought.

Discussion of Issues

These will be divided into issues which are non-obstetric in nature and then will cover those related specifically to pregnancy.

What Is the Imaging Modality of Choice for Evaluation of the Acute Abdomen in Pregnancy for Non-obstetric Causes?

Right Lower Quadrant Pain: Rule Out Appendicitis

Summary of Evidence The incidence of acute appendicitis in pregnancy is approximately 1 in 1500–1700 pregnancies [6, 7]. Imaging pathways supported by ACR and several obstetrical societies including ACOG and SOGC favor the use of ultrasound as the first imaging modality in most cases (strong evidence), followed by MRI (moderate evidence) [5, 8, 9]. However, the use of CT should not be excluded when maternal safety and health are at stake (insufficient evidence) [5].

Supporting Evidence The diagnosis of appendicitis may be more challenging in pregnant women due to the displacement of the normal location of the appendix by the enlarging uterus. Patients who are pregnant and develop appendicitis are more likely to present with ruptured appendicitis compared to nonpregnant patients, thus increasing risk of maternal morbidity and fetal loss. Performing laparoscopic surgery in cases of negative appendicitis is also associated with a slight increase in premature delivery, and thus the risks and benefits of imaging and intervention must be carefully weighed [10–12].

In pregnant patients with right lower quadrant pain, the ACR recommends starting with an abdominal ultrasound, including graded compression, to look for the appendix. This was given a rating of eight out of nine for appropriateness [6]. Reported sensitivity and specificity of graded compression sonography for appendicitis in pregnancy patients vary depending on stage of pregnancy, patient body habitus, and degree of displacement of the normal position of the appendix by the gravid uterus. Published sensitivity of sonography varies significantly, with older studies reporting sensitivities as high as 85–100% [13, 14], while newer studies which compared ultrasound directly to other cross-sectional imaging modalities reported much lower sensitivities, in the range of 20–36% [14]. Specificity is high with a range of 92–96% [15].

Following an equivocal ultrasound result, MRI without intravenous contrast is the next most commonly recommended imaging. In a study by Pedrosa et al., of pregnant patients with suspected appendicitis, a normal appendix was identified in only 2% of pregnant patients with ultrasound versus 87% on MRI with oral contrast [16].

A meta-analysis by Blumenfeld et al., in 2011, evaluated the use of MRI without intravenous contrast after equivocal ultrasound, for diagnosing acute appendicitis. They demonstrated a sensitivity of 90.5%, specificity of 98.6%, PPV of 90.4%, and NPV of 99.5% [17].

Another pooled analysis performed by Long et al. supported the diagnostic strength of unenhanced MRI for diagnosing appendicitis. The specificity was 98–100% and NPV 94–100%. Authors indicated that finding a normal appendix on MRI was highly accurate in excluding appendicitis (Table 26.2) [18].

When considering CT for diagnosing acute abdominal pathology in pregnancy (including ischemic bowel, bowel obstruction, complications of Crohn's disease, or nondiagnostic findings on MRI and ultrasound), the ALARA principle should be used. Oral and rectal contrasts are rarely required but could be considered on a case-by-case basis. In a meta-analysis by Basaran et al., sensitivity and specificity of CT with intravenous contrast in pregnancy have been reported to be 86% and 97%, respectively [19–21]. Negative predictive value is up to 99% [22].

Cost-Effectiveness Analysis

A study by Katsenberg reviewed cost-effectiveness of various diagnostic modalities used when ultrasound is equivalent for diagnosing appendicitis. The study found MRI to be more cost-effective compared to CT and diagnos-

tic laparotomy, costing $6767 per quality-adjusted life-year gained. Despite the small increased rates of childhood cancer, CT is more cost-effective than diagnostic laparotomy when MRI is not available [2].

Right Upper Quadrant Pain from Hepatobiliary Causes

Summary of Evidence As in nonpregnant patients, sonography is the imaging modality of choice for assessing the gallbladder for calculi. This is given a recommendation of nine out of nine by the ACR appropriateness guidelines (strong evidence) [6]. MRCP is the next preferred test in cases of inconclusive US (insufficient evidence) [6].

Supporting Evidence Cholelithiasis is present in 12% of pregnant women, but symptomatic in only 0.1–0.3% [23]. Other considerations of RUQ pain in pregnant women include HELLP (hemolysis, elevated liver enzymes, and low platelets) syndrome, fatty liver of pregnancy, as well as Budd-Chiari syndrome (which pregnant women are at increased risk for due to their hypercoagulable state). In addition, other considerations of hepatobiliary abnormalities which are not necessarily related to pregnancy itself need to be considered. This includes acute hepatitis, pancreatitis, and primary sclerosing cholangitis [24]. Finally, in pregnant patients presenting with RUQ pain, the diagnosis of acute appendicitis should still be considered, since the cecum is progressively displaced cranially by the gravid uterus and, thus, acute appendicitis, particularly in the third trimester, can present with symptoms referred to the right upper quadrant [25].

ACR appropriateness criteria rated ultrasound as nine out of nine in pregnant women with fever and leukocytosis [26]. Ultrasound in pregnant and nonpregnant patients has high positive and negative predictive values (92.2% and 95.2%, respectively) for diagnosing cholecystitis [27]. However sensitivity of ultrasound in the detection of common bile duct stones is lower, with some publications quoting sensitivity of only 20–38% [28].

MRCP is considered eight out of nine for pregnant patients with right upper quadrant pain according to the ACR appropriateness criteria [26]. This is considered the preferred test to follow an inconclusive US. It is useful to evaluate the entire biliary system and to assess other causes of acute abdominal pain without exposing the patient to ionizing radiation [25].

According to the meta-analysis in nonpregnant patients by Kiewiet et al., the summary sensitivity for MRI is 85% (95% CI: 66%, 95%) and specificity is 81% (95% CI: 69%, 90%) with similar diagnostic performance expected in the earlier stages of pregnancy [29].

Acute Bowel Pathology: Bowel Obstruction

Summary of Evidence Intestinal obstructions complicate between 1 in 1500 and 3000 pregnancies. Maternal and fetal mortality rates have been noted to be as high as 6% and 25%, respectively [30, 31]. ACR appropriateness guidelines give MRI a recommendation of 4/9 for assessing small bowel obstruction, but specifically indicate that this is the most appropriate imaging for pregnant women, in addition to children (moderate evidence) [32]. According to the SOGC 2014 recommendations for imaging in pregnancy, gadolinium contrast agents may be used in pregnant women when the benefits outweigh the potential risks (SOGC level of evidence III-C, limited evidence) [5]. As with appendicitis, use of CT for suspected bowel obstruction, or ischemic bowel, should not be excluded when maternal safety and health are at stake (SOGC level of evidence III-C, limited evidence) [5].

Supporting Evidence Most bowel obstruction is related to adhesions, though volvulus, hernias, and other causes have been reported. Crohn's disease should also be considered in the differential diagnosis, particularly if the patient has a prior history of this diagnosis. In patients post Roux-en-Y gastric bypass, there is an increased risk of internal hernia (including Petersen-type hernia and jejuno-jejunal anastomosis hernias) [33, 34].

MRI should be considered for evaluation of the location of the transition point and cause of

obstruction, particularly in clinically stable patients with signs of partial or incomplete obstruction. T2-weighted images including HASTE or True FISP may be used for anatomic evaluation. Fat-saturated T2-weighted images also depict free fluid and edema around bowel loops [34, 35]. Specific absorption rate (SAR) limits should be observed in all cases of MRI when used in pregnancy. These SAR limits are determined for each pulse sequence to ensure that the increase in body temperature is less than 0.5 °C [36]. Gadolinium-containing intravenous contrast agents are considered category C medications by the US Food and Drug Administration and are generally not recommended in pregnancy [37]. However the SOGC recommends using gadolinium contrast materials in pregnant women when the benefits outweigh the risks [5]. This was given a SOGC level III-C grading recommendation (limited evidence) (Table 26.1) [5].

In comparison, according to publications by Bourjeily and Atwell, there have been no documented cases of neonatal hypothyroidism from the use of water-soluble iodinated contrast agents used for CT. Given that all newborns are already screened for congenital hypothyroidism at the time of their birth, no extra attention is necessary if a fetus is exposed to CT-iodinated contrast agents in utero [38, 39].

There are situations after birth where new mothers require urgent MR imaging. In these cases, SOGC guidelines indicate that the use of gadolinium in a lactating patient is safe and lactation can continue without any need to stop for any period of time [5]. This was based on a study published by Chen which indicates that only 0.1% of intravenously injected gadolinium is excreted via the mother's milk and, of that, only 1% is absorbed by the lactating baby [37].

Table 26.1 Canadian task force on preventive health care (SOGC) gradation of levels of evidence

Level	Quality of evidence assessment
I	Evidence obtained from at least one randomized controlled trial
II-1	Evidence is from well-designed controlled trials but without randomization
II-2	Evidence is from well-designed cohort or case-control studies, preferably from >1 research group
II-3	Evidence is obtained from comparisons between times and places with or without the intervention. Dramatic results in uncontrolled experiments
III	Opinions of respected authorities, based on clinical experience, descriptive studies, or reports of expert committees
Grade	**Classification of recommendations**
A	Good/strong evidence to recommend the clinical/preventive action
B	Fair/moderate evidence to recommend the clinical/preventive action
C	Current evidence is conflicting. No recommendation for or against the use of a clinical/preventive action. Other factors may influence decision-making
D	Fair/moderate evidence to recommend against the clinical preventive action
E	Good/strong evidence to recommend against the clinical preventive action
L	Insufficient evidence to make a recommendation.

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Flank Pain: Renal Colic

Summary of Evidence Sonography is the preferred imaging modality to assess the kidneys, ureters, and bladder during pregnancy. This is supported by ACR, ACOG, and SOGC recommendations (strong evidence) [5, 6, 10]. No clinically significant biological effects have been reported with in utero exposure to sonography. However, Doppler US can produce high-intensity energy and should be used judiciously. As a second-line option, non-contrast MR urography (MRU) is a safe and viable option (limited evidence).

Supporting Evidence 1 in 3300 pregnancies is affected by ureteral calculi [40]. Most calculi pass on their own, but up to 30% may cause some degree of renal obstruction, leading to increased risks of complications including superimposed infection and premature labor [41]. Anatomical changes in the renal collecting system in pregnancy include dilatation of the renal calyces and ureters due to the compression by the pregnant

uterus in addition to the effect of progesterone on the ureteral smooth muscle. These findings are more commonly seen on the right side during the late second and early third trimesters of pregnancy, and the appearance can mimic true hydronephrosis from pathologic obstruction [42].

Sonographic evaluation for ureteric calculi is complicated by overlapping features of physiologic dilation of the renal collecting system of pregnancy which is seen in 60 to over 90% of pregnant patients, more often in the third trimester due to compression of the ureter by the enlarging, gravid uterus. The absence of ureteric jets is not especially helpful for differentiating calculi from physiologic obstruction since 15% of asymptomatic pregnant women have been shown not to have ureteric jets [43].

Resistive index (RI) calculation (peak systolic velocity of intrarenal blood flow minus the end-diastolic velocity divided by the peak systolic velocity) has shown some promise in pregnancy with a value of 0.7 to have moderate sensitivity and specificity (77% and 83%). Also, a change in RI of >0.06 has also been shown to be associated with acute obstruction [44]. However, these techniques are not specifically recommended by ACR, ACOG, or SOGC. Computed tomography has a higher sensitivity (93% vs. 79%) and NPV (71% vs. 46%) for the detection of calculi when compared to sonography. The combination of calculi plus obstructive signs has sensitivity and specificity of 100% for CT and of 100% and 90%, respectively, for US. The 11 calculi which were not detected by US in this study all passed spontaneously (10 were <5 mm) [45]. Both techniques showed similar extraurinary pathology. Computed tomography is the most accurate technique for the detection of ureteral calculi. However, the combination of radiography and US is an alternative to nonenhanced CT with good practical value, even if the sensitivity and specificity are somewhat lower.

As second-line imaging, MR urography (MRU) is a safe and viable option. In MRU during pregnancy, the pyelocalyceal system and the ureters are visualized using heavily T2-weighted images. Currently, MRU, not CT urography, is the preferred imaging test in children and pregnant patients with dilated collecting systems based on the ALARA principle which aims to minimize the use of ionizing radiation in these patient populations. However, few studies have assessed PPV, NPV, and accuracy of MRU, nor have comparison studies been performed comparing accuracy of MRU to CT urography [20].

Pathologic obstruction of the ureter is characterized by an abrupt caliber change of the ureter, enlargement of the kidney, and, in optimal circumstances, visualization of the obstructing calculus in the ureter. In comparison physiologic dilation typically seen associated with pregnancy occurs in the mid ureter with gradual tapering. MR is relatively insensitive for the detection of calcium-containing structures, including calculi; thus the diagnosis of ureteral calculi often relies on detecting secondary signs of obstruction [46]. Some of these secondary signs visible on MRI include the presence of a standing column of urine below the level of the pelvic brim, an abrupt ending of the ureter (implying an obstructing calculus at this point), and the presence of perinephric or peri-ureteral edema [46].

Although the protocol for MRU in pregnancy varies between institutions, it is performed without intravenous contrast. Sequences typically include using coronal and axial half Fourier single-shot turbo spin-echo sequence (HASTE). T2-turbo spin-echo sequences with fat suppression may provide more detailed T2-weighted information and detect filling defects in the ureters. T1-weighted images with in- and out-of-phase imaging may help detect blood (bright on T1-weighted images) or fat-containing lesions [47].

Trauma

Summary of Evidence

1. Trauma is the leading non-OB/GYN cause of maternal death, and all efforts are directed to maximize maternal outcomes in order to provide best chances for fetal survival. In patients who are hemodynamically unstable, urgent surgical intervention is warranted, often bypassing any cross-sectional imaging. In clinically stable pregnant patients, the type of imaging chosen depends on location of injury and severity [48].

2. Sonography can be used initially if the mother is clinically stable, and fetal viability can be assessed, but a negative US in the setting of high clinical suspicion does not exclude traumatic injury. In addition, a negative US does not exclude placental abruption. When serious injuries are suspected, then contrast-enhanced CT is warranted (moderate evidence) [49].
3. CT is warranted to evaluate for trauma, and the risks of iodinated contrast and ionizing radiation are outweighed by the benefit of having a timely, accurate diagnosis to direct medical and surgical care (moderate evidence) [50].
4. Trauma patients may undergo repeat CT scans depending on their injuries and hospital course which may expose the fetus to higher doses of ionizing radiation. Fetal doses below 50–100 mGy are not a reason for termination, and a standard CT of the abdomen and pelvis is in the range of 25 mGy [8, 9]. With repeat exposure to CT scans, consultation with a radiation physicist and genetic counselor should be considered.

Supporting Evidence Trauma affects 7% of pregnant women, with the highest incidence occurring in the third trimester, most frequently due to MVC, followed in frequency by assault and falls [23, 48, 49]. The rate of fetal loss from trauma is dependent on severity of the trauma and area of injury. Obstetric complications from trauma include placental abruption, uterine rupture, direct injury of the fetus, and maternal demise leading to fetal demise. Non-obstetric trauma includes all other abdominal organs; however, splenic rupture is the most commonly organ injured, leading to free intraperitoneal blood [51]. In a study by Brown et al., sensitivity of ultrasound for detecting blunt abdominal trauma was 80%, and specificity was 100% [52]. However, when high-energy trauma is reported, a negative ultrasound should not preclude additional imaging when clinical symptoms warrant it.

In the setting of trauma when CT is being considered for diagnostic purposes, intravenous iodinated contrast agents are necessary for detection of solid organ injury. Maternal and fetal risks related to CT imaging include exposure to ionizing radiation and to iodinated contrast. Potential effects of ionizing radiation to the fetus are teratogenic and carcinogenic. Neither effect is considered significant at a standard CT abdomen and pelvic dose of 25–30 mGy, and the small risk incurred from ionizing radiation is outweighed by the benefit of a definitive diagnosis provided by the CT study which could avoid potential maternal and fetal morbidity and mortality from delayed or missed diagnosis [5, 50].

Neonatal hypothyroidism has been associated with some iodinated agents taken during pregnancy. However, given the doses used for a single CT, the risks are considered very low [50]. Breastfeeding can continue after administration of iodinated contrast agents [53].

What Is the Imaging Modality of Choice for Evaluation of the Acute Abdomen in Pregnancy for Obstetric Causes?

Ectopic Pregnancy

Summary of Evidence Ectopic pregnancy affects 1–2% of pregnancies and presents with abdominal pain in the first trimester. It is a leading cause of pregnancy-related morbidity and mortality [54]. Ultrasound is the recommended modality to assess a suspected ectopic pregnancy, in addition to any other cause of first trimester bleeding (strong evidence). The use of sonography has been given an appropriateness criteria rating of nine out of nine by the ACR (strong evidence) [55]. However, non-contrast-enhanced MRI can also be used for this diagnosis, particularly when ultrasound findings are equivocal. The ACR appropriateness rating is six out of nine (moderate evidence) [55].

Supporting Evidence During sonographic evaluation, the presence of a yolk sac within a gestational sac in the endometrium is the first definitive sign of an intrauterine pregnancy. Other specific imaging findings which are helpful for identifying an intrauterine pregnancy include the pres-

ence of a "double decidual sign." This finding has been found to be nearly 100% specific (though only 64% sensitive) for early intrauterine pregnancy [56].

Assessment of the adnexal regions is still recommended when an intrauterine gestation is identified. This is done to rule out other abnormalities that may be the cause of pain including rupture of a corpus luteum cyst, ovarian torsion, or, very rarely, a heterotopic ectopic pregnancy, which occurs in 1:10,000 cases [57]. A heterotopic pregnancy is defined as one gestational sac within the endometrial cavity, and a concomitant gestation elsewhere, usually in the adnexa. This occurs more commonly in women who are using assisted fertility techniques [57].

Abruption

Summary of Evidence Ultrasound should be used to evaluate for suspected placental abruption but is limited in sensitivity; a negative ultrasound does not exclude the presence of placental abruption (limited evidence). The role of CT remains controversial: although placental abruption can be identified by CT, the overall performance has not been compared to US (insufficient evidence). Given the risk of ionizing radiation, CT is not the recommended test to diagnose placental abruption. The accuracy of MRI to diagnose placental abruption has not been assessed in studies (insufficient evidence).

Supportive Evidence Placental abruption, in which the placenta separates from the uterus usually due to shear forces, occurs in 1% of pregnancies and can lead to fetal death in 20–60% [58, 59]. Placental abruption is the most common injury to the uterus after blunt trauma, occurring in 30–50% with major trauma [48, 60]. This diagnosis is the leading cause of vaginal bleeding in the second half of pregnancy, affecting 15–30% with third trimester bleeding, and is a significant cause of morbidity and mortality to the fetus. The larger the abruption, the worse the fetal outcomes, with abruption involving more than 50% of the placenta frequently associated with fetal death [48, 61]. When the mother is hemodynamically stable, ultrasound is used to assess for placental abruption. However, the sensitivity is limited, with 50–80% of cases undetected by sonogram, i.e., false negative [62, 63]. The evidence supporting the accuracy of CT in diagnosing placental abruption is weak, with studies limited by small sample size or the lack of a reference standard [58, 64]. Although the sensitivity for CT was found to be 100% for both readers in one study [58], the sensitivity was 42% based on the original dictated report, and the false-positive rate was a high as 20%, suggesting that directing the readers' attention to the possibility of placental abruption increased their awareness of looking for the condition but also resulted in overcalling. Due to ionizing radiation, CT should not be used to diagnose placental abruption. However, in instances when CT is obtained in a pregnant patient, the radiologist should be aware of the appearance of placental abruption. No studies have been performed to assess the comparative accuracy of ultrasound to CT, nor have studies been performed to assess the accuracy of MRI for diagnosing placental abruption.

Ovarian Torsion

Summary of Evidence Sonography is the imaging modality of choice to make this diagnosis [65], and the ACR appropriateness guidelines recommend transabdominal and transvaginal ultrasound to diagnose this condition as well as other causes of acute gynecologic pain in pregnant women (strong evidence) [9]. These recommendations are given a rating of nine out of nine. However, MRI can also be used for this diagnosis, particularly when ultrasound findings are equivocal (strong evidence). The ACR appropriateness rating is six out of nine [9].

Supportive Evidence Ovarian torsion is considered a surgical emergency requiring untwisting when possible. Oophorectomy may be required if the diagnosis is delayed. Up to 20% of ovarian torsion cases occur during pregnancy, and this is an important differential diagnostic consideration of the acute abdomen. Imaging findings of torsion, regardless of the modality used, include an enlarged ovary, more centrally located in the pelvis, with associated thickening of the fallopian

tube. Often on sonography a swirling of vessels in the adnexal area can be identified particularly on cine clips [66]. These imaging findings help to differentiate torsion from other nonsurgical diagnoses such as pelvic inflammatory disease [67].

T2-weighted images are most commonly used to assess for suspected ovarian torsion when using MRI [68]. On T2-weighted images, the acutely torsed ovary is typically enlarged and edematous, which is reflected by some degree of higher signal intensity in the stromal tissue. Ovarian follicles are arranged peripherally and may contain hemorrhage which is readily detected by MRI. Most hemorrhagic ovarian follicles or cysts are imaged in the subacute phase of extracellular hemoglobin when they are hyperintense on T1 weighting and can be high or intermediate to low signal intensity on T2-weighted images. Old blood products are comprised of hemosiderin and are hypointense on T1W and T2W [68].

Take-Home Tables and Figure

Table 26.1 lists the SOGC gradation of levels of evidence, and Table 26.2 summarizes the sensitivity and specificity of US and MRI for diagnosing acute abdomen in pregnancy. Figure 26.1 is an imaging algorithm for pregnant patients present with acute abdominal symptoms.

Take-Home Points

In pregnant patients presenting with acute abdomen from any cause, abdominal US is the usual first imaging modality recommended, followed by non-contrast-enhanced MRI. These imaging modalities have excellent safety profiles for both the mother and fetus. However, there are cases where CT should be considered, especially if other imaging is inconclusive or unavailable. Also, for pregnant patients with suspected serious traumatic thoracic or abdominopelvic injuries, further evaluation with CT is warranted:

- Efficient triage of pregnant patients with abdominal pain in all three trimesters is needed to reduce risk of morbidity and mortality of the mother and fetus.
- When considering any imaging, especially when considering CT, the principle of ALARA should be followed while still allowing a technically diagnostic imaging study to be performed.
- Written consent should be obtained when imaging pregnant women with CT or MRI [23].

Imaging Case Studies

Case 1

Figure 26.2a–d discusses a 29-year-old woman with a history of Roux-en-Y gastric bypass who presents to the ER with intermittent, worsening abdominal pain

Case 2

Figure 26.3a–d discusses a 24-year-old woman, 15 weeks pregnant, with right upper quadrant pain

Case 3

Figure 26.4a, b discusses a 33-year-old woman, 29 weeks pregnant, who has upper and lower abdominal pain following a motor vehicle accident at 70 km/h

Case 4

In Fig. 26.5, a 30-year-old woman, 16 weeks pregnant, presents with right upper quadrant pain

Suggested Imaging Protocols

(a) Sonography is recommended by ACOG and ACR appropriateness criteria when assessing pregnant patients with abdominal pain from obstetric and non-obstetric causes. The use

Table 26.2 Summary of sensitivity and specificity for US and MRI for diagnosing acute abdomen in pregnancy

Disease	Modality	Sensitivity	Specificity	Predictive Values	Comments
Appendicitis	US	Wide range reported in the literature	92–95%		Depends on stage of pregnancy, patient body habitus, etc.
	MRI	90.5%	98.6%	PPV = 90.4% NPV = 94–100%	
	CT	86%	97%	NPV = 99%	
Acute cholecystitis	US	92%	95%		
	MRCP	81%	85%		
Renal colic	US	79–90%			
	CT	93–100%	>98%		
	MRI	–	–	–	Insufficient evidence
Trauma (hemodynamically stable)	US	80%	100%	–	Brown et al. [46]

US ultrasound, *CT* computed tomography, *MRI* magnetic resonance imaging, *MRCP* magnetic resonance cholangiopancreatography, *PPV* positive predictive value, *NPV* negative predictive value

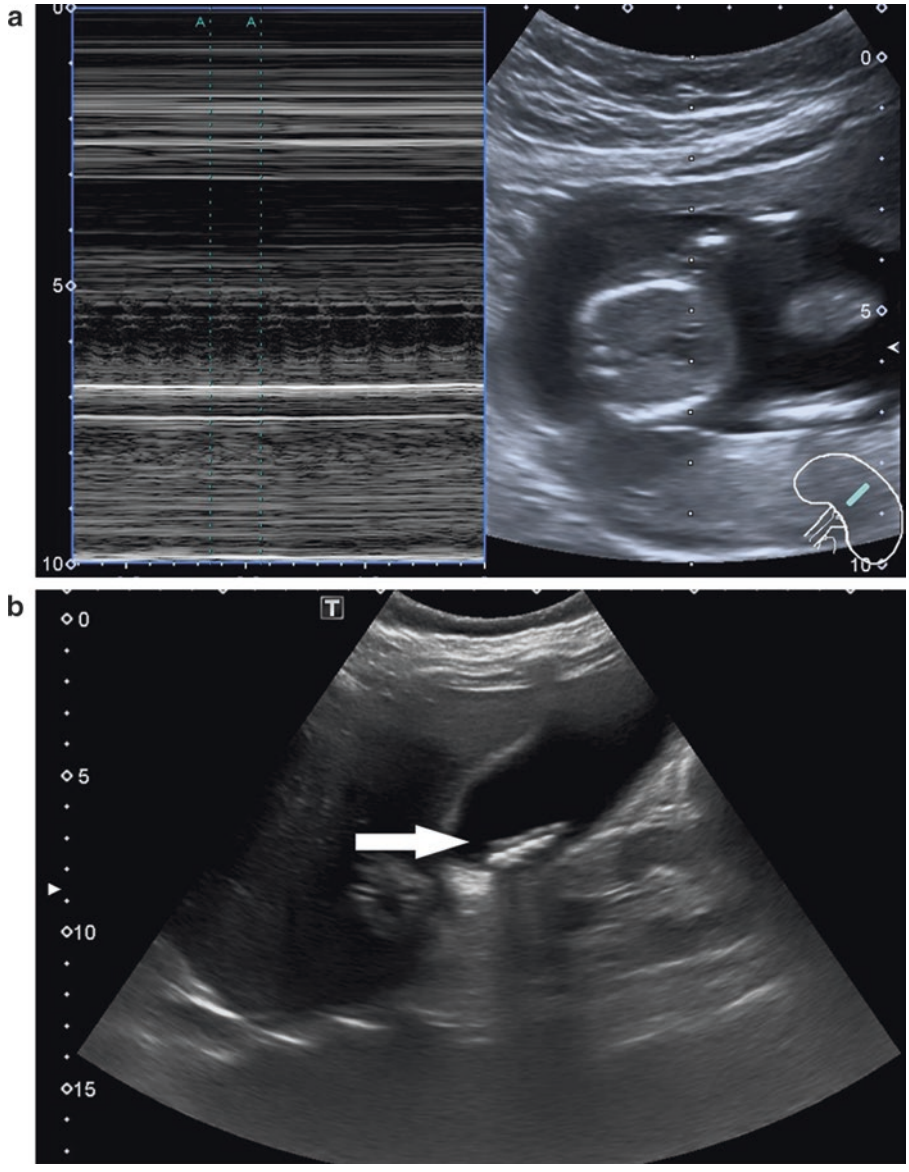

Fig. 26.2 (**a**)–(**b**) 24 year old woman, 15 weeks pregnant () presents with right upper quadrant. Sonographically, there were gallstones in the gallbladder (*arrows in b*) and a sonographic Murphy's sign. However, there was no significant gallbladder wall thickening

of graded compression, whereby increasing pressure is placed on the abdomen to displace overlying bowel loops out of the field of view, is specifically recommended by the ACR appropriateness criteria particularly in cases of suspected appendicitis [9, 10].

(b) MRI is often considered the second-line imaging in pregnancy when sonographic findings are equivocal in non-trauma cases:
- Written consent should be obtained prior to performing MRI in a pregnant patient. Of note, no long-term sequelae have

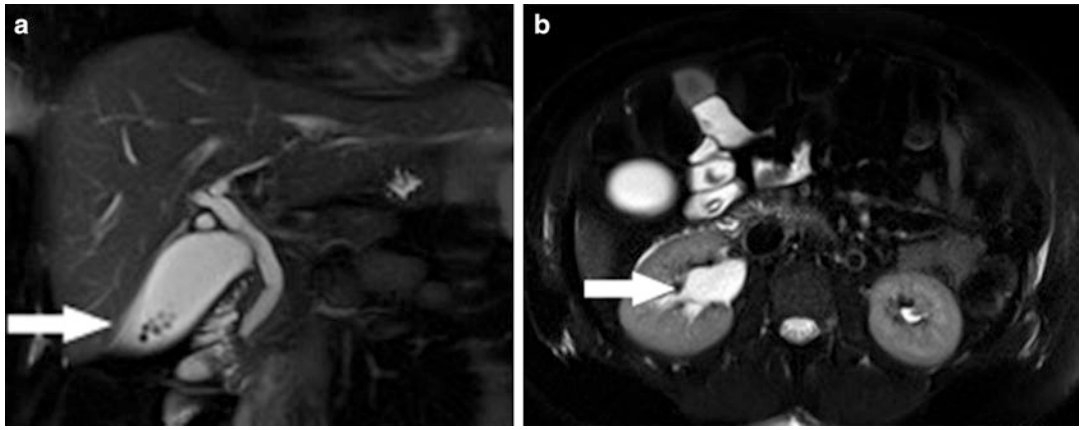

Fig. 26.3 (**a**)–(**b**) The pain worsened the next day, thus a MRI was performed. On the T2 weighted images, there was visualization of the gallstones (arrow in a) and some distension of the gallbladder but no CBD calculi and no pericholecystic fluid or significant gallbladder wall thickening. Incidental note was made of physiologic dilation of the right renal collecting system (arrow in b) which persisted throughout the pregnancy but resolved after delivery

been identified in cases of inadvertent MRI exposure in first trimester [5]. Imaging should be tailored to the area of concern and should be overseen by a radiologist to obtain only those sequences which are required to make the diagnosis. One of the goals is to reduce the SAR (specific absorption rate) of deposited energy and heat in the patient and fetus.

- Multi-planar, single-shot fast spin-echo T2-weighted images are most commonly used initially to get an overview of the area of concern.
- Fast spin-echo T2-weighted fat-suppressed images of the abdomen are used to identify edema and free fluid.
- Unenhanced T1-weighted images, in- and opposed-phase images, can be used to look for intracellular fat. T1-weighted fat-saturated images can be used to look for blood products as well as lesions containing fat (e.g., dermoid).
- Axial bright blood vascular sequences (without saturation bands above or below) can help differentiate blood vessels from the appendix.
- MRCP can be used in cases of pancreaticobiliary abnormalities

(c) CT should be considered when maternal symptoms warrant further imaging and sonography is inconclusive or nondiagnostic and in the trauma setting. CT is a significant consideration in cases of acute ischemic bowel where intravenous contrast is required (especially since gadolinium contrast agents in MRI are considered class C drugs). When CT is being considered, the area of concern should be adequately collimated to reduce the cranio-caudal extent of scanning when possible. Intravenous contrast may be used as needed.

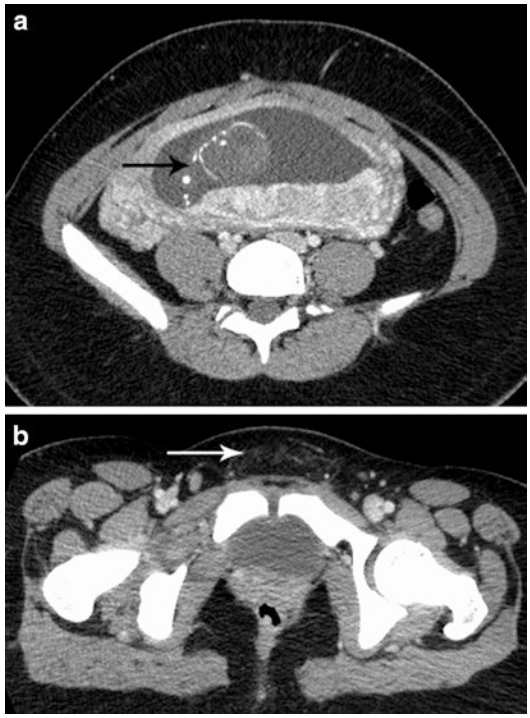

Fig. 26.4 (**a**)–(**b**) 33 year old, 29 weeks pregnant (*arrow in a*) was in a motor vehicle accident at 70 km/h. She presented with upper and lower abdominal pain. She was hemodynamically stable and although the initial sonogram in the emergency department did not show free fluid, she underwent CT to exclude occult solid organ injury. All solid organs were intact. Only some bruising was noted over the lower, anterior pelvis from the seatbelt (*arrows in b*). The patient was observed in hospital for 24 hours and then discharged home in good condition

Future Research

- Long-term safety of exposure to MRI and gadolinium-based contrast materials in utero
- Radiation risks to fetus from intrauterine exposure to ionizing radiation
- Positive predictive value and negative predictive value of MR urography in assessing renal and ureteric calculi in pregnancy

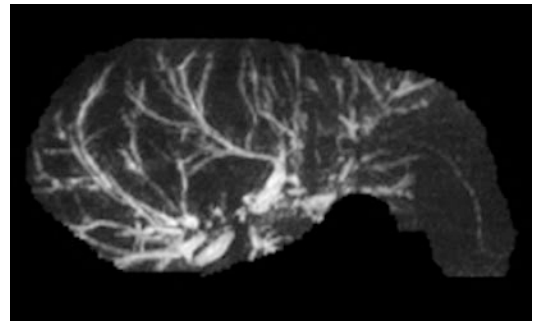

Fig. 26.5 30 year old woman presented with right upper quadrant pain but no discrete abnormality seen on ultrasound (not shown). However, on the MRCP images, note was made of several focal areas of narrowing with interspersed beading of the intrahepatic bile ducts. This was a first presentation of primary sclerosing cholangitis. 6 months post-partum, the patient was also diagnosed with Crohn's disease

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