There is evidence that emergencies in pregnancy are subject to mismanagement; however, the percentage of error in the diagnosis of emergencies in pregnancies has not been studied in-depth. The purpose of this article is to review the most common emergencies in pregnancies, focusing the attention on errors in images. The topics covered are divided into gynecological and nongynecological, and for each pathology, the possible errors in the diagnostic pathway, the possible technical errors in the execution of the examination, and in the end, the possible errors in interpretation of the images have been dealt with. These last two entities are often connected, in the fact that a substandard examination can stem interpretation errors, but the systemization of the error is a valid approach in helping to learn from these errors, reducing the possibility that the same error can represent itself.

In this progressive increase of the diagnostic research in pregnancies, various factors concur to make the work of the emergency radiologist insidious for the analysis of a pregnant patient in emergency. The emergency radiologist must have a complete preparation that comprises traumatic and non-traumatic pathologies that are not limited to one organ or area. The radiologist must be able to answer any issues from brain and bone marrow problems going from the thoracic and abdominal pathologies to the osteoarticular ones. This all implies a profound knowledge of anatomy and of the physiology and pathology of the whole body. Not least important is the understanding of pregnancy pathologies that, in addition, expand the knowledge that an emergency radiologist must possess.

The emergency radiologist must be also capable of using all the imaging techniques, from traditional radiology to magnetic resonance (MR). In this regard, no discipline in the medical environment has had such a sudden technical evolution in the past 20 years like the diagnostics for imaging. It has led to the multiplication to the nth power the quantity of imaging that the radiologist has to analyze, thus radically modifying the type of work. The emergency radiologist has to decide in a short lapse of time without the possibility of a second consultation and in difficult environmental conditions. Differences between initial emergency CT reports by general radiology or residents and secondary interpretation by specialist revealed discrepancy rates of 6%-27%. This occurs even in the most organized emergency departments (EDs), from the moment that the rush of work is not foreseeable and commitment during a work shift is not standardizable. Error rates...
in reporting abdominal CT have been shown to more than double when a radiologist reports >20 studies a day. Therefore, the error is always in waiting, and it is even more so in gynecological emergencies that are low in frequency, and this is one of the causes of reduced experience and of the consequence of the faltering diagnosis and delayed therapy. The scarce familiarity of the radiologist in the clinical practice of this situation renders the appropriate technical execution of the examination more difficult. The capacity to interpret the images and the lack of knowledge of the awareness of the pathology make the relationship of interaction with the clinician, who requires an urgent examination, more difficult. Clinical information played an extremely important role in the analysis and interpretation of CT scans and follows Bayesian logic (conditional probability). When clinical information was correct, 83% of reports became more accurate. Even in the radiological diagnosis of the gynecological emergencies, the cause of the errors is often multifactorial and frequently coexist. Like in the diagnostics of other pathologies, risks are described that can lead to an error linked to a substandard technique, failure of perception, lack of knowledge, or misjudgment.

Errors are shaped and provoked by upstream systemic factors, such as organizational culture, risk management, or lack of resources. This last aspect can be particularly critical in hospitals where a distinct and structured gynecological department does not exist, with all the implications that follow. In the management of an emergency pregnancy, the radiologist must know when to be able to perform the examination with ionizing radiation like CT, and when instead it is unadvisable to avoid possible damage to the fetus due to radiation. This especially in situations like pulmonary embolism and abdominal-pelvic emergency that can be evaluated with alternative techniques, like CT. The use of CT in pregnant women affected by the period of pregnancy in which the emergency occurs. Although the safety of radiation exposure during pregnancy is a common concern, a missed or delayed diagnosis can pose a greater risk to the woman and her pregnancy than any hazard associated with ionizing radiation. In many cases, the perception of fetal risk is higher than the actual risk.

The purpose of this article is to review the most common emergencies in pregnancies, focusing the attention on errors in images. The topics covered are divided into gynecological and nongynecological, and for each pathology, the possible errors in the diagnostic pathway, the possible technical errors in the execution of the examination, and in the end, the possible errors in interpretation of the images have been dealt with. These last two entities are often connected, in the fact that a substandard examination can stem interpretation errors, but the systematization of the error is a valid approach in helping to learn from these errors, reducing the possibility that the same error can repeat itself. The systematization of the error and the importance of not criminalizing those that commit the mistake should be the source of the meetings, which allow to understand the cause of the error so that it is never repeated in the future.

Non-Gynecological Emergencies

Brain

The pregnant patient presenting neurological problems poses both diagnostic and therapeutic challenges, often forcing the clinician to rely on neuroimaging as part of the workup. Although neuroimaging findings are not always specific, the judicious use of diagnostic neuroimaging in the pregnant patient plays an important role in diagnosing and treating many of the neurological pathologies. Involve and inform the radiologist and obstetrician when deciding on CT and MRI in the pregnant patient; some CT and MRI examinations can be modified to provide diagnostically critical information while exposing the embryo or fetus to as little risk as possible. MRI is thought to be preferable to CT, although conclusive data to this effect are not available. During head CT examination of the mother, the fetus is exposed only to radiation that is scattered through the body; therefore, shielding of the abdomen does not significantly reduce the minimal fetal radiation dose, but may help to alleviate maternal anxiety. MRI should be avoided in the first trimester unless no alternative exists. Iodinated contrast is rated by the Food and Drug Administration as a category B drug. Gadolinium should be avoided during pregnancy unless no alternative exists—gadolinium is rated by the Food and Drug Administration as a category C drug.

Cerebral venous thrombosis (CVT) and the posterior reversible edema (PRES) syndrome are among the pathologies that are radiologically more insidious in pregnancy.

Cerebral Venous Thrombosis

Pregnancy and the puerperium are common causes of transient prothrombotic states. CVT accounts for 6% of maternal deaths. CVT may occur anytime during the course of pregnancy and the puerperium, but most pregnancy-related CVT occurs in the third trimester or puerperium. Pregnancy induces several prothrombotic changes in the coagulation system that persist at least during early puerperium. Approximately 2% of pregnancy-associated strokes are attributable to CVT. There is an increased risk of CVT in young mothers and after cesarean delivery. The diagnosis of CVT is typically based on clinical suspicion and imaging confirmation. CVT has a variety of clinical presentations ranging from severe headache to deep coma, depending largely on the severity and extent of thrombosis, as well as the mode of onset. The most common presentation includes headache (97%), followed by seizure attacks (47%) and paresis (43%). The headache of CVT is typically described as diffuse and often progresses in severity over days to weeks. A patient with CVT may present focal neurologic deficits depending on the sinus or major cerebral vein involved. The superior sagittal sinus is most commonly involved in nonseptic CVT, whereas cavernous and lateral sinus thromboses are more often the result of sepsis. Delays in diagnosis of CVT are common and significant. The median delay from onset of symptoms to hospital admission was 4 days, and from symptom onset to diagnosis it was 7 days.
Diagnostic Pathways

Neuroimaging remains the main cornerstone for the diagnosis of CVT. Although a plain CT or MRI is useful in the initial evaluation of patients with suspected CVT, a negative plain CT or MRI does not rule out CVT. CT without contrast media is often normal but may demonstrate findings that suggest CVT. Anatomic variability of the venous sinuses makes CT diagnosis of CVT insensitive, with results on a plain CT being abnormal only in ≈30% of CVT cases. A venographic study (either CT-V or MR-V) should be performed in suspected CVT if the plain CT or MRI is negative or to define the extent of CVT if the plain CT or MRI suggests CVT. These are the latest recommendations of the American Heart Association/American Stroke Association on the diagnosis and management of CVT, to which we must accompany the inevitable consideration on the use of contrast media in pregnancies, remembering that it is indispensable to always evaluate the potential risk benefit before administering iodine- or gadolinium-based contrast media. The iodine goes through the placenta, but studies on animals have not shown risks for the fetus. Growth retardation and congenital anomalies were observed with the administration of gadolinium doses between 2 and 7 times superior to those used in humans. However, it is also true that the gadolinium was inadvertently administered also for clinical purposes, without observing the undesired effects for the fetus. MRI is more sensitive than CT scan in early detection of thrombosis and more accurate in depicting the extent and complications of CVT. Therefore, with a clinical doubt of CVT, Magnetic Resonance Venography (MRV) is the method to use where it is obviously readily available, otherwise the confirmed diagnosis must be obtained with the CT.

Technical Pearls

There are no substantial technical errors that can be made using CT of the brain. Because of the dense cortical bone adjacent to dural sinus, bone artifact may interfere with the visualization of enhanced dural sinus. The deep venous system is readily seen on CT and MRI, and may be less impacted by artifact because of the separation from bony structures. The most commonly used MRV techniques are time-of-flight (TOF) MRV and T1 3D contrast-enhanced MR. Phase-contrast MRI is used less frequently, because defining the velocity of the encoding parameter is both difficult and operator dependent. The 2-dimensional TOF technique is the most commonly used method, currently used for the diagnosis of CVT, as it has excellent sensitivity to slow flow compared with 3-dimensional TOF. The MRV has to be accompanied with a standard study of the brain in which the T2 gradient-echo sequence cannot be neglected of, but it can be useful to improve the accuracy of CVT diagnosis.

Imaging Pitfalls

The positive findings of intraluminal thrombus are the key to a confident diagnosis of CVT by CT or MRI. Unfortunately, these findings are not always evident, and the diagnosis rests on nonfilling of a venous sinus or cortical vein. Given the variation in venous anatomy, it is sometimes impossible to exclude CVT on noninvasive imaging studies. Anatomic variants of normal venous anatomy may mimic sinus thrombosis, including sinus atresia/hypoplasia (Fig. 1), asymmetric sinus drainage, and normal sinus filling defects related to prominent arachnoid granulations (Fig. 2) or intrasinus septa. Angiographic examination of 100 patients with no venous pathology showed a high prevalence of asymmetric lateral...
(transverse) sinuses (49%) and partial or complete absence of 1 lateral sinus (20%). Flow gaps are commonly seen on TOF MRV images, which sometimes affect their interpretation. The hypoplastic dural sinus may have a more tapering appearance than an abrupt defect in contrast-enhanced images of the sinus (Fig. 3). Sinus signal-intensity variations may also affect the interpretation of imaging in the diagnosis of CVT. Flow gaps are commonly seen on TOF MRV images, which sometimes affect their interpretation. The hypoplastic dural sinus may have a more tapering appearance than an abrupt defect in contrast-enhanced images of the sinus (Fig. 3). Sinus signal-intensity variations may also affect the interpretation of imaging in the diagnosis of CVT.36 In the first week, venous thrombus frequently appears as isointense to brain tissue on T1-weighted images and hypointense on T2-weighted images owing to increased deoxyhemoglobin. By the second week, thrombus contains methemoglobin, which results in hyperintensity on T1- and T2-weighted images.30 With evolution of the thrombus, the paramagnetic products of deoxyhemoglobin and methemoglobin are present in the sinus. A thrombosed dural sinus or vein may then demonstrate low signal on gradient-echo T2-weighted MR sequence.30,36 A potential pitfall at the junction of the straight sinus and vein of Galen on TOF MRI is the appearance of absence of flow if image acquisition is in an axial plane to the skull. This pitfall may be overcome with contrast-enhanced MRI and diffusion-weighted imaging.30,36

Posterior Reversible Edema Syndrome
The association of PRES with toxemia of pregnancy is well established.37-39 Preeclampsia develops in approximately 5% of pregnancies and eclampsia, in approximately 1 in 3000 births with current management.40 Eclampsia develops before gestation in 50% of patients, interpartum in 25%, and within >48 hours of delivery in 25%. Although most women are hypertensive at toxicity, blood pressure is reported as normal or only minimally elevated in 23% of patients.41 The placenta is thought to be the primary cause of toxemia, with placenta removal and fetal delivery considered curative (hypertensive disorders of pregnancy). In a single reported case, delayed eclampsia appeared to have been associated with retained placental fragments.42 PRES presents as headaches, seizures, and sometimes cortical blindness or other focal neurologic deficits in women with preeclampsia or eclampsia. As the name indicates, the symptoms are reversible with control of hypertension and delivery. However, some patients with a similar clinical presentation have an infarction rather than reversible symptoms.

Diagnostic Pathways
The most sensitive method for the identification of PRES is MR, and it is the method to be used where it is obviously readily available, otherwise the confirmed diagnosis must be obtained with CT, although it is known that the sensitivity of CT is lower than the sensitivity of MR (Fig. 4A and B).

Technical Pearls
It is fundamental to include in the protocol the Fluid-Attenuated Inversion Recovery sequences (FLAIR) and Diffusion Weighted Imaging (DWI). FLAIR imaging best shows the edema at the gray-white junctions.43 Diffusion-weighted images allow differentiation of vasogenic and cytotoxic edema, predicting which patients will develop infarctions rather than having reversible symptoms and imaging abnormalities.44

Imaging Pitfalls
PRES is a neurotoxic state coupled with a unique CT or MRI appearance. At CT/MR imaging, the brain typically demonstrates focal regions of symmetric hemispheric edema (Fig. 4C and D). The parietal and occipital lobes are most commonly affected, followed by the frontal lobes, the inferior temporal-occipital junction, and the cerebellum.45 Lesion confluence may develop as the extent of edema increases. MR diffusion-weighted imaging was instrumental in establishing and consistently demonstrating that the areas of abnormality represent vasogenic edema.45 The edema usually completely reverses (Fig. 4E and F). The basic PRES pattern resembles the brain watershed zones, with the cortex and subcortical and deep white matter involved to varying degrees.45-47 Focal/patchy areas of PRES vasogenic edema may also be seen in the basal ganglia, brain stem, and deep white matter (external/internal capsule).48 When they accompany hemispheric or cerebellar PRES, it is easy to recognize these areas as companion lesions. Present in isolation or when the hemispheric pattern is incompletely expressed (partial/asymmetric), the diagnosis of PRES can be challenging.49 If cerebellar or brain stem involvement is extensive, hydrocephalus and brain stem compression may occur.45 Focal areas of restricted diffusion (likely representing infarction or tissue injury with cytotoxic edema) are uncommon (11%-26%) and may be associated with an adverse outcome.49 Hemorrhage (focal hematoma, isolated sulcal/subarachnoid blood, or protein) is seen in approximately 15% of patients.49

Thorax
Respiratory complications during pregnancy are not unusual and can be life-threatening. Understanding of the cardiore-
spiratory changes during pregnancy is essential for the diagnosis and treatment of emergencies in normal pregnant women and in women with underlying cardiopulmonary diseases. Among the thoracic emergencies, pulmonary embolism represents one of the most discussed with, a major pre-occupation for the radiologist.

**Pulmonary Embolism**

Three studies on amply covered case studies have demonstrated that pulmonary embolism in pregnancy takes place in about 1-2 cases every 7000 pregnancies (less than previously assumed), and that most cases occurred postpartum, in par-

**Figure 4** Posterior reversible edema syndrome. CT scan (A and B) shows normal parenchymal findings. Axial MR FLAIR images (C and D) at symptoms onset show a wide signal intensity abnormality involving symmetrically the frontoparietal (arrows in C) and occipital cortex (arrows in D) and subcortical white matter. Axial MR FLAIR images (E and F) obtained 6 days later show an almost complete resolution of the symmetric lesions previously revealed.
ticular with preeclampsia, after a cesarean, and in the case of multiple births. Pregnant women have a 5-fold increased risk of venous thromboembolism when compared with non-pregnant women of similar age. Venous stasis is the most important factor, but pregnancy-related hypercoagulability, decreased fibrinolysis, and familial predisposition are also implicated. The risk of thrombosis is greatest during the third trimester and immediate postpartum period.

Diagnostic Pathways
During pregnancy, the first diagnostic examination to perform is compression ultrasound (US) of the lower extremities that does not use ionizing radiation and allows to diagnose with elevated accuracy (sensitivity 95% and specificity 98%), deep vein thrombosis of the lower extremities. From the moment that the treatment of deep vein thrombosis and pulmonary embolism is the same, and, in the case of the compression US of the lower extremities being positive, it is not necessary to perform other diagnostic investigations. It is however necessary to remember that in pregnancies, iliac vein thrombosis is more frequent than those of the veins of the lower extremities, which are more difficult to diagnose with US respect to MR (Fig. 5). Therefore, in the case of a negative examination, it is nonetheless necessary to exclude, with the imaging technique, a pulmonary embolism. In pregnancies, the position of the radiologist is always that of avoiding ionizing radiation or, at least, to use the method that produces the least amount of radiation possible but still allowing a trustworthy diagnosis. Most (69%) Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) II investigators recommend pulmonary scintigraphy, and 31% recommend CT angiography, but it has now been cleared that CT angiography of the thorax provides irradiation to the fetus inferior to that of ventilation/perfusion pulmonary scintigraphy (V/Q SPECT), even using half of the dose of technetium-99m labeled albumin macroaggregate (99mTc-MAA) normally required, providing a superior accuracy. Recent estimates indicate a 0.026-mSv fetal dose from standard dose CT and 0.013-mSv dose from a multidetector CT. This is lower than the 0.4-0.6 mSv estimates for V/Q SPECT. However, V/Q SPECT scans are generally preferred over CT in pregnant patients, given the high maternal breast radiation dose delivered by CT.

The doses to the fetus are higher because it was found that free pertechnetate crosses the placenta. Therefore, the radiologist cannot make the mistake of refusing to perform a CT pulmonary angiography of the thorax where a pulmonary embolism is suspected, also considering the technical devices of latest generation of CT scan, to reduce the dose to the fetus (Table 1). CT angiography of the thorax also has the advantage, contrary to the pulmonary V/Q SPECT, of being able to detect alternative diagnosis to the pulmonary embolism that can present itself with the same symptoms, like pneumonia and pleural effusion. Unfortunately, it is not even possible to rely on the MR to avoid using ionizing radiation, in that the administration of gadolinium is not considered safe, because of studies on animals have shown toxic effects, like delay in growth and congenital anomalies. Although there are no studies that demonstrate the toxicity of gadolinium on the human fetus, American College of Radiology (ACR) considers its use unadvisable.

Technical Pearls
A careful diagnosis of pulmonary embolism with CT angiography cannot prescind from a correct technical formulation.

| Table 1 Technical Pearls to Reduce the Dose to the Fetus in the Execution of CT Pulmonary Angiography for Pulmonary Embolism |
| Set the inferior limit of the scan just below the xiphoid process (to exclude the upper abdomen) |
| Increase the pitch and thicken the detector collimation |
| Eliminate the lateral scout view |
| Reduce the field of view and decrease the peak values for kilovolt peak and milliampere seconds (but not at the cost of image quality) |
| Do not scan the pelvis and lower extremities for possible deep vein thrombosis (ie, do not perform CT venography) |
| Use lead shielding (which is not an effective barrier for internal scatter but can decrease patient anxiety) |
to detect eventual pitfalls of a technical nature, anatomic or pathologic that can lead to false positives or examinations that are of a substandard quality diagnosis. Among the possible errors due to technical factors, we can include the wrongly set window display, with the excessive brilliance of the vessel that masks the presence of small embolisms or flaps; some authors advise the use of a specific window for embolism (W700;C100). The use of bolus-timing software usually results in a properly timed study. If the contrast bolus arrives too early or too late, an embolus may not be seen easily. The excessively concentrated contrast media in the superior vena cava causes a stellate morphology artefact (Fig. 6) with the masquerading of the right pulmonary artery and the right superior lobar artery; the lavage of the superior cava venous is useful in these cases by administering a physiological solution after the contrast media bolus (using a double injector). The algorithm of reconstruction is also important, because of the use of an algorithm of reconstruction or, a filter that is too hard, can simulate the presence of embolisms (Fig. 7). A mistaken time bolus with scanning that is too early or too tardy determines a low-density intraluminal from failed arrival of contrast media or from late dilution.

**Diagnostic Pitfalls**

The errors of interpretation of the image are essentially tied to the successful technique of the examination. There can, in fact, be no doubts on the presence of embolisms in the lumen of the pulmonary arteries if the examination is technically valid. Among the anatomic factors, one must remember the nearness of the vessel to the hilar lymph nodes; it is necessary to know the exact position of these lymph nodes and to use fine collimation supplemented by multiplanar reconstruction (MPR). It is also necessary to evaluate the vessels along all their course to distinguish the veins (scarcely homogeneous density) from the arteries. It is, however, useful to know that the veins do not pass alongside the bronchi and that in the lower lobes, the veins have a horizontal course. The MPR can be very useful to solve diagnostic problems that can be found on the images in the axial plane (Fig. 6).

**Abdomen and Pelvis**

The diagnosis of maternal diseases of the abdomen and pelvis in pregnancy is a complex clinical problem because both symptoms and maternal anatomy are altered. Nausea, vomiting, abdominal pain, altered bowel movement, and constipations are commonly found in the pregnant population as a whole, and physicians and patients usually attribute them to the usual manifestations of pregnancy. These symptoms may mask and delay in initiating the diagnostic workup for clarify their origin (Fig. 8). Clinicians frequently rely on imaging to distinguish diagnoses; and when US fails, physicians must choose between CT and MRI for further workup. No consensus exists regarding an algorithm for imaging abdominal complaints in pregnant patients.

**Figure 6** Pitfall in diagnosis of pulmonary embolism. A 35-year-old patient in 3rd trimester with suspicious pulmonary embolism. Axial CT angiography (A) shows stellate morphology artifact due to mistaken time bolus, which hides the right pulmonary artery (arrowhead) and an apparent filling defect (arrow) in the left lower lobe pulmonary vessel due to interface between the air in the bronchus end the contrast media in the vessel. Coronal reconstruction image (B) shows no filling defect in the lumen of the left lower lobe pulmonary vessel (arrows).

**Figure 7** Pitfall in diagnosis of pulmonary embolism. A 34-year-old patient in 2nd trimester with suspicious pulmonary embolism. Axial CT angiography show an apparent filling defect in the lumen of the right lower lobe pulmonary vessel (arrow). Edge-enhancing reconstruction algorithms can create the false-positive appearance of acute PE. Although edge-enhancing algorithms are appropriate for review of images in lung windows, smoothing algorithms are more appropriate for review of the images in soft-tissue windows.
Gastrointestinal Changes

Many physiological changes occur in women during pregnancy, and these changes impact virtually every organ system. These adaptations allow the mother to support the metabolic demands of the fetoplacental unit and withstand the hemorrhage associated with delivery. These changes may mimic disease, and they also may alter a patient’s response to stress from trauma or surgery.

As pregnancy progresses, the growing uterus displaces the diaphragm, the stomach, the intestines, and the kidneys upward, and the lower rib cage circumference expands by 5 cm. These anatomic alterations can confound diagnosis of intraabdominal processes.

Stretching of the peritoneum acts to desensitize it, thereby complicating the abdominal examination.

Elevated progesterone levels, mechanical factors, and the enlarging uterus, all contribute to delayed gastric emptying and increased stomach volume, determining nausea and vomiting in up to 50% of women during pregnancy, primarily in the first trimester. Delayed gastric motility and prolonged gastrointestinal transit time may lead to constipation and alter the bioavailability of medications. The renal collecting system becomes more dilated as early as the first trimester, leading to hydronephrosis. The physiologic dilatation of the upper collecting system should be considered when interpreting radiographic studies evaluating for possible obstruction. Compression of the ureters (of the right ureter more than the left) results in urine stasis, thereby predisposing the pregnant woman to urinary tract infections, nephrolithiasis, and pyelonephritis. The bladder loses tone, resulting in frequency, urgency, and incontinence, the last of which is compounded in the third trimester as the fetal head engages in the pelvis.

Acute Appendicitis

Acute appendicitis accounts for 25% of surgeries for nonobstetric indications in pregnancy and complicates every 1 in 1500-2000 pregnancies. It is equally distributed in different months, but the perforation is more frequent in the third trimester. In pregnant patients, it can be difficult to diagnose acute appendicitis, because the patient rarely presents the classic symptoms like fever, nausea, vomiting, and a localized pain in the right iliac fossa. Therefore, the gestational uterus determines the distinction between a parietal and visceral peritoneum, thus resulting in a reduction of somatic localized pain. An elevated white count or elevated sedimentation rate is an unreliable parameter during pregnancy. The diagnosis of appendicitis in pregnancies can be particularly difficult, above all, in the second-third trimester when the gravid uterus displaces the appendix upward and laterally toward the right upper quadrant. After 24 weeks’ gestation, the appendix is shifted superiorly above the right iliac crest, and the tip of the appendix is rotated medially toward the uterus. By late pregnancy, the appendix may be closer to the gallbladder than McBurney point, occupying the right upper quadrant. In the second-third trimester, 69% of perforated appendix manifest themselves, clearly superior to the 31% in the first trimester. This increased incidence may reflect a reluctance to operate on a pregnant woman, and a delay in diagnosis commonly noted with appendicitis in pregnancy. Maternal
and fetal morbidity and mortality correlate with perforation, which usually results from delayed diagnosis, and its associated complications. Other studies show the rate of negative appendix in the presence of suspected phlogiston framework to be elevated, 22%-55% explained by the propensity of some surgeons wanting to avoid the perforation and avoid the correlated maternal-fetal risks. A rapid diagnosis is therefore fundamental to guarantee the outcome of the surgery before complications occur. It is therefore that imaging has such a fundamental role.

Diagnostic Pathways
US is always the first examination to perform when acute appendicitis in pregnancies is suspected. In a study on 42 women with suspected appendicitis during pregnancy, the US presented 100% sensitivity, 96% specificity, and 98% accuracy in the diagnosis of appendicitis. The accuracy of the method is however in relation to different factors like the operator's experience, the physical condition of the patient, intestinal meteorism, and above all, it diminishes with the progress of the pregnancy, especially in the third trimester. Therefore, if the result of the US is negative or doubtful, without an alternative diagnosis, other imaging techniques are necessary to diagnose or exclude appendicitis. This is because the treatment chosen is surgery even if it is not free from some risks like preterm labor, fetal loss, and decreased birth weight, even considering that there has been a reduction in the past. MR is the method to perform in cases in which the MR scan is collocated in the ED or is however available in a short time. Various studies show the reliability of MR in diagnosing appendicitis (Fig. 9) and other abdominal-pelvic pathologies that can be present with similar symptoms with elevated sensitivity and specificity. However, if MRI is not available, CT does impart very useful information, and failure to diagnose the mother’s medical problems correctly can pose a much greater risk to the fetus than the radiation from a diagnostic examination. In a recent retrospective study, the sensitivity and specificity of CT for appendicitis were 92% and 99%, respectively.

Figure 9 Acute appendicitis. Axial (A) and coronal (B) T2 images show a thickened appendix (arrows in A and B); the thickening is appreciable in all its length.

Technical Pearls
When the uterus displaces and rotates the organs and the only US approach possible is that in left lateral decubitus, it can be more difficult technically to perform the US examination. The failing collaboration and/or an apnea inferior to 20-25 seconds prejudices the success of the sequence MR necessary, such as T1-weighted, T2-weighted, and fat saturation T2-weighted sequences on the axial level and/or coronal. A possible limitation of MRI is the need of a skilled image interpretation with possible significant differences in the identification of the cause of acute abdomen between reviewers with disparate training in body MR and limited comfort of emergency radiologist in reading cases. In this regard, the reported excellent interobserver agreement is an important additional result suggesting a possible widespread use of MR in the evaluation of acute pain during pregnancy.

Imaging Pitfalls
Early inflammation of the appendix may be confined exclusively to the distal tip; the proximal portion of the appendix can appear normal in size. An examination can be false-negative if only the base and proximal portion of the appendix are identified and the inflamed distal tip is not evaluated. Therefore, it is essential to visualize the entire length of the appendix. The tip of the appendix can be identified owing to its termination as a blind pouch. A retoceleal appendix can be difficult to visualize from a standard anterior approach. Sagittal or coronal images of the right iliac fossa via a lateral flank approach often permit visualization of a retrocecal appendix by scanning directly posterior to the cecum (Fig. 10). The inflamed appendix is rarely enlarged, measuring 1.5-2.0 cm in anteroposterior diameter. Because of its unusual size, the appendix can be misconstrued as small bowel. Identification of a distal tip is often the key to correctly identifying the loop of bowel as an abnormal appendix. Locating the appendix on MRI can be troublesome, as the position is variable in pregnancy and often in the right upper quadrant in the later stages of pregnancy. Despite optimization of the image acquisition, anatomical detail can be confusing. The terminal ileum and appendix may be mistaken for each other. The right gonadal
Vein is often dilated in pregnancy and can simulate the appendix (Fig. 11). Several conditions have been recognized that can lead to a false-positive MR diagnosis of appendicitis, including a fluid-filled terminal ileum, terminal ileum inflammation such as in Crohn disease, cecal diverticulitis, small bowel diverticulitis, fluid in the right lower quadrant from a ruptured right ovarian cyst, and intra-abdominal ascites. A false-negative result will occur if a distended fluid-filled appendix is mistaken for the terminal ileum (Fig. 12). If ascites is present because of a comorbid condition, periappendiceal inflammation from appendicitis may be obscured.

**Small Bowel Obstruction**

When bowel obstruction occurs, it complicates 1 in 3000 pregnancies and is the third most common reason for a non-obstetric laparotomy. Approximately 60%-0% of cases are caused by adhesions, and 25% are the result of volvulus. By comparison, in nonpregnant patient, only 3%-5% of obstructions are caused by volvulus. The risk of volvulus is highest during rapid changes in uterine size, usually during the early portions of the second trimester and in the postpartum period. Redundant bowel (usually the cecum) can be rotated around a fixed point, causing obstruction during this time. Intussusception accounts for most of the other cases of bowel obstruction. The impact of obstruction can be significant. Perdue et al reported on 66 patients undergoing laparotomy for obstruction. Maternal mortality was 6%, and the fetal loss rate was 26%. Typical pregnancy symptoms can cause delayed diagnosis of intestinal obstruction. Usual symptoms include crampy abdominal pain, constipation, and nausea/emesis. Most pregnant patients experience some or all of these symptoms, especially in the first trimester. The gravid uterus can mask the abdominal distention seen with obstruction. Severe or persistent vomiting should alert the consulting physician to look for other etiologies, including obstruction.

![Figure 10](image1.png) Acute appendicitis. US image (A) obtained with lateral flank approach shows retrocecal inflamed appendix (thickened and edematous walls). Coronal MR T2 image (B) confirmed retrocecal appendicitis.

![Figure 11](image2.png) Pitfall (error in interpretation) in diagnosis of acute appendicitis. US shows an expanded tubular structure on the right side, considered as acute appendix A. Sagittal (B) and coronal (C) MR steady-state sequences reveal that the tubular structure depicted by US is a dilated ovarian vein (arrows).
When an obstruction occurs, there is significant risk for severe morbidity or mortality for both mother and fetus, and treatment needs to occur as soon as possible. Delays owing to errors in diagnosis, delayed diagnosis, or reluctance to operate during pregnancy all add to increased risk.

**Diagnostic Pathways**

Minimal delay in treatment is key, and early surgical consultation is necessary to evaluate bowel viability. US may demonstrate fluid-filled bowel loops, while also excluding alternative causes in the biliary and renal systems. Plain abdominal radiography should not be dismissed as out of hand, as it may reveal highly suggestive appearances, although the reported sensitivity in pregnant patients has been found to be variable. Plain abdominal films can be helpful for diagnosis, showing the typical air-fluid levels and dilated bowel loops in 82% of cases. If plain film radiographs are normal, and obstruction is still suspected, contrast studies should be obtained, given the high risk of fetal death with delayed treatment. In addition, MRI may be used. Early imaging and diagnosis are warranted because bowel necrosis can occur rapidly (Fig. 13).

**Technical Pearls and Diagnostic Pitfalls**

Detection of bowel wall pneumatosis may be very challenging at MR imaging, as air is devoid of signal with all MR pulse sequences. In-phase and opposed-phase gradient-echo (GRE) images may help demonstrate this finding because a
characteristic blooming effect occurs on the in-phase images (acquired with a longer echo time) compared with the opposed-phase images in the presence of air due to susceptibility effects. Single-shot fast spin-echo (SE) images can help confirm this finding by demonstrating an area of very low signal intensity within the wall and showing the mucosa separating this area from the bowel lumen. Ancillary findings, including bowel wall thickening, mesenteric fat stranding, or air in the portomesenteric venous system provide further evidence that supports the diagnosis of pneumatosis. However, CT should be considered to confirm or exclude this finding when MR imaging features are equivocal.

Renal Colic

Obstructive urinary calculi complicate approximately 1 in 3300 pregnancies.\textsuperscript{73} In a pregnant patient with clinical evidence of renal colic but no history of stone disease, the diagnosis of a ureteral stone may be a challenge. In fact, 28% of pregnant patients with renal colic and abdominal pain had an incorrect admitting diagnosis based on clinical evaluation, which underscores the limitations of clinical diagnosis; these diagnoses included appendicitis, diverticulitis, and placental abruption.\textsuperscript{74} Fortunately, approximately 70%-80% of ureteral calculi in pregnant patients have been reported to have passed spontaneously.\textsuperscript{75} However, if misdiagnosed or inadequately treated, urolithiasis can be complicated by pyelonephritis and premature labor induced by renal colic, with or without coexisting infection.\textsuperscript{75} Imaging is complicated by the normal physiological hydronephrosis that occurs in pregnancy.

Diagnostic Pathways

US is operator dependent, and sensitivity ranges from 34% to 92.5%.\textsuperscript{75} Despite this US remains the initial study of choice, but that additional imaging by MR, noncontrast low-dose CT or intravenous (IV) pyelogram may be required if US is negative. Therefore, evaluation of a pregnant patient with renal colic and hematuria may ultimately require other imaging tools. MR urography should be considered as a second-line test when use of US fails to establish a diagnosis, and there are continued symptoms despite conservative management. CT is extremely accurate in diagnosing or excluding ureteral calculi. Fetal exposure may be reduced by using narrow collimation and faster image acquisition, but CT is best avoided in routine use even if the perception of risk is greater than the risk itself. Furthermore, inaccurate, missed, or delayed diagnosis may represent a more significant risk to the patient than the radiation risk.

Technical Pearls and Diagnostic Pitfalls

A frequently encountered diagnostic challenge is the difficulty in distinguishing hydronephrosis from physiological dilatation, the latter of which is the most common cause of renal pelvic and ureteral dilatation during pregnancy. Moreover, false-negative results may occur in acute obstruction before hydronephrosis appears, whereas false-positive results may occur if there is nonobstructive dilatation of collecting systems. US can be helpful in demonstrating asymmetric hydronephrosis, and the stone itself may be seen if it lies at the ureteropelvic or ureterovesical junction. In the latter case, a transvaginal or transperineal approach may be necessary, but still the diagnosis is often elusive. This modality may also be of value in demonstrating asymmetric ureteral jets (ie, the absence of detectable flow or continuous low-level flow). However, nonobstructing stones or those producing low-grade obstruction may not demonstrate asymmetry.\textsuperscript{74} Approximately 15% of asymptomatic pregnant women have been reported to have absent unilateral jets.\textsuperscript{74} Patients should be imaged in the contralateral decubitus position to decrease false-positive results.\textsuperscript{74} A limited IV pyelogram has classically been used, but it is often difficult to interpret due to the hydroureter that typically accompanies pregnancy and the problem of visualizing the ureteral calculus when the gravid uterus is superimposed. MR urography is a relatively new development, with some limitations in delineating extrinsic vs intrinsic obstruction due to low spatial resolution and limited visualization of small calculi.\textsuperscript{75} Multisection MR urography, using thinner sections, may reveal a stone as a negative filling defect. However, a filling defect in the ureter at MR urography is nonspecific; it is difficult to distinguish stones from blood clots, debris, or polypoid lesions.
Gynecological Emergencies

First trimester pregnancy complications such as abdominal pain and vaginal bleeding are common presenting complaints in the ED. Bleeding during pregnancy has been associated with significant maternal and fetal morbidities and even mortality. Although vaginal bleeding occurs mainly during the first trimester, it can appear at any stage of the pregnancy and during the postpartum period. This sometimes life-threatening event requires an extensive workup to recognize its cause and establish a rapid and effective therapeutic approach. US finding of a clear intrauterine pregnancy, in many instances, minimizes the possibility of ectopic pregnancy and can decrease ED throughout time and decrease morbidity. The scope of practice for pelvic US in ED will vary depending on individual experience, comfort/skill level, and departmental policies.

Early Pregnancy Failure

Early pregnancy failure may present itself with vaginal bleeding and/or abdominal pain. Up to 70% of spontaneous abortions exhibit an abnormal karyotype; two-thirds will be autosomal trisomies, whereas the remainder involves monosomy X, structural rearrangements, and other aneuploidies. Only a small percent of early losses related to aneuploidy are due to parental balanced translocations or inversions. In the absence of a karyotypic abnormality, pregnancy failure can be associated with luteal phase defects, immunologic factors, infection, alcohol, smoking, or lethal genetic abnormalities.76,77

Diagnostic Pathways

US plays a major role in parental reassurance where fetal cardiac activity is seen and is pivotal in the assessment of early pregnancy complications, such as vaginal bleeding.

Technical Pearls and Diagnostic Pitfalls

Recent advice concludes that a diagnosis of an empty sac (previously named blighted ovum or anembryonic pregnancy) should not be made if the sac diameter is <20 mm (Fig. 14), and viability should not be confirmed or refuted if the visible crown-rump length (CRL) is <6 mm, as only 65% of normal embryos at that stage will display cardiac activity.77 Repeat transvaginal US examination after at least a week showing identical features and/or the presence of fetal bradycardia is strongly suggestive of impending miscarriage.77 The possibility of incorrect dates should always be considered. Differential diagnoses include threatened, inevitable, and missed abortion. The latter can be further subdivided into anembryonic pregnancy (blighted ovum) or embryonic demise. Other differential diagnoses include ectopic pregnancy (Fig. 15) and molar pregnancy (Fig. 16).

Figure 15 Pitfall (error in interpretation) in US diagnosis of ectopic pregnancy. A 28-year-old woman presents with amenorrhea for 6 weeks, abdominal pain, and vaginal bleeding. Her β-HCG level was elevated. Pelvic US was reported by a resident radiologist. He reported multiple small intramural leiomyoma and an empty uterus, suggesting ectopic pregnancy. The patient was informed of the findings and treated with methotrexate. The following morning, the radiology attending reviews the US and amends the report, officially reading it as “normal intrauterine pregnancy (arrow).”

Figure 16 Molar pregnancy at 8 weeks gestational age in patient with pelvic pain, bleeding, and very high level of β-HCG. Sagittal transvaginal image (A) shows the endometrial cavity to be distended with echogenic material with multiple small cysts compatible with a molar pregnancy. However, US does not allow proper evaluation of the myometrial invasion (stars). Axial T2-weighted sequence image (B) shows molar pregnancy without complete myometrial infiltration (arrows). It is always important to administer the contrast medium to assess myometrial infiltration. The evaluation of the vasculature is an important aspect to assess myometrial infiltration and eventual response to chemotherapy.
Ectopic Pregnancy
Ectopic pregnancy occurrence is 1:150 births. It is currently the leading cause of pregnancy-related death during the first trimester in the United States, accounting for 9% of all pregnancy-related deaths. Main risk factors are tubal surgery, infections, prior ectopic, and use of intrauterine device (IUD).

Most common symptoms are amenorrhea, abdominal pain, adnexal mass, and vaginal bleeding.

Ectopic pregnancy is usually tubaric, and less frequently, it is ovarian, interstitial, heterotopic, and cervical. Interstitial ectopic pregnancy regards the intramural portion of the tube covered by myometrium, and it can break later than the tubaric pregnancy, occurring about 12-16 weeks; therefore, interstitial pregnancy is burdened by the highest rate of morbidity and mortality. Since intrauterine pregnancy might coexist with appendicitis, ruptured hemorrhagic cysts, adnexal torsion, and ectopic pregnancy symptoms may overlap, any young female patients with acute abdominal pain should have pregnancy and ectopic pregnancy excluded.

Diagnostic Pathways
Diagnosis of ectopic pregnancy is based on both US and Beta human chorionoc gonadotrophin (β-HCG) blood levels. Combination of high-resolution transvaginal or transabdominal US and evaluation of quantitative β-HCG blood levels usually allow earlier diagnosis and treatment of abnormal pregnancy. The most common US finding (78% of cases) of ectopic pregnancy is an adnexal mass or thick-walled cyst formed by trophoblastic tissue surrounding the chorionic sac, with color Doppler high flow (ring structure) and pelvic free fluid. Absence of intrauterine gestational sac and β-HCG value 1000-1500 UI/L has been shown to have high prediction of ectopic pregnancy. If the diagnosis is not clear but the patient is stable, serial quantitative β-HCG values over 48 hours are also very helpful. In normal pregnancy, the β-HCG level should at least double every 2 and 3 days, whereas in abnormal pregnancies, including ectopic pregnancy, the doubling rate is slower with a <66% increase over 48 hours. If a quantitative β-HCG level exceeds 6500 IU/L with no evidence of an intrauterine pregnancy using abdominal US, a diagnostic laparoscopy should be performed. CT scan findings are nonspecific in ectopic pregnancies and pose a hazard of ionizing radiation, which may be harmful to normal pregnancies. MRI can be more helpful in several situations as to differentiate intrauterine pregnancy associated with congenital structural uterine abnormalities from an ectopic interstitial pregnancy or to clarify US findings. Moreover, MRI can add precise information in case of hemorrhagic ascites and hematosalpinx, and it can allow characterization of an adnexal mass and localization of hematoma.

Technical Pearls
To attain the highest diagnostic percentage possible, you must be ever conscious of the possibility of pregnancy in females aged 12 to 50 years. Conducting a detailed physical examination and obtaining a complete history from physicians are for the deletion of errors related to poor knowledge of the necessary information to be able to perform and interpret the imaging. Just consider that a negative pregnancy test result does not exclude tubal pregnancy, because the placenta in tubal location can be either compromised or nonviable and, therefore, not able to produce enough HCG for a positive pregnancy test result. Transabdominal and endovaginal US are recommended in all studies. Nevertheless, although transabdominal US is always available, endovaginal US is not always available in ED. The transabdominal US performance might make diagnosis difficult because the patient can be uncooperative because of abdominal pain or meteorism can prevent correct detection of both ovaries and uterus. In a patient in stable condition, a full bladder should be present as a proper transabdominal US window. In unstable patients in whom an expeditious diagnosis is needed, the time delay for the bladder to fill may be undesirable. Transabdominal and/or endovaginal US may be performed in these patients with an empty bladder. It can happen that physicians do not report a possible pregnancy, therefore, if β-HCG
blood levels examination is not performed, ectopic pregnancy and rupture of ectopic pregnancy can be misdiagnosed (Fig. 20), as other gynecologic and not gynecologic diseases can have overlapping clinical presentation.

Therefore, evaluation of β-HCG blood levels is mandatory in all cases of child-bearing age, young women with acute abdomen. The cases in which patients have hemoperitoneum and radiologists decide on CT or MRI performance, IV contrast agent administration is important. Contrast agent administration should always be decided compatibly with renal function, but the absence of IV contrast agent administration can prevent the localization of the bleeding, and it may underestimate bleeding.80

**Pitfalls in Imaging**

Despite US is the first imaging modality of choice, there are several problems of differential diagnosis. A corpus luteum might have the same “ring of fire,” typical of ectopic gestational sac, as the detection of an echogenic mass can be due either to an ovarian mass (echogenic cyst, tumor) or to an ectopic pregnancy (Fig. 21). Likewise, hemoperitoneum can be associated both to ruptured ectopic pregnancy and ruptured hemorrhagic cyst.79 CT imaging of a ruptured ectopic pregnancy may be indistinguishable from a ruptured hemorrhagic ovarian cyst. Thus, hemoperitoneum imaging can be similar in many abdominal emergencies, whereby if radiologists do not interview patients, do not speak to clinicians or surgeons, they might make the wrong diagnosis. Instead, MRI ectopic pregnancy diagnosis is usually burdened by less interpretation problems enough that MRI is performed with no technical problems so with right sequences (T1, T2, fat suppression sequences), IV contrast agent administration, and no artifacts.79

**Ovarian Torsion**

The adnexal torsion is defined as the rotation of the ovary and, sometimes, of the fallopian tubes, on its own vascular peduncle, with a partial or total interruption of the blood flow and consequently ischemia until necrosis. It is a pathology that is more frequent in the fertile age with an incidence of around 3%. The most important risk factors are pregnancy, induction of ovulation, presence of benign and malignant tumors with the consequent volumetric increase of the ovaries, predisposing factor during childhood and adolescence, and the hypermotility of the mesosalpinx.81,82 Around 60% of the torsions occur on the right attachment, and in 20% of the cases, during the pregnancy. The clinical presentation is not always well defined. The most common symptom is represented by pain, which manifests itself suddenly in the inferior quadrants of the abdomen. The pain can be stinging or oppressive with irradiation of the inguinal or lumbar regions. Sometimes, it can be associated with nausea and vomiting. With abdominal palpitation, it is possible to evi-

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**Figure 18** US at 7 weeks’ gestational age in patient with pelvic pain and bleeding. Transvaginal US shows empty endometrial canal and abnormal right adnexal mass (A). Axial (B and C) and coronal (D) T2-weighted sequences images show two ectopic pregnancies respectively located in the tubal (arrow) and in the adnexa (arrowhead).
ence, but not always, signs of peritoneal irritation. During gestation, the torsion is more frequent in the rapid changing phases of the dimensions of the uterus, therefore between the VIII and the XVI week and then during the puerperium. The diagnosis of such a pathology is not always easy, as it can imitate important pathologies like the rupture of ovarian cysts, pelvic inflammatory disease (PID), ectopic pregnancies, but also extragynecological pathologies, such as stones in the urinary tract, cholecystitis, and strangled mesenteric. The timeless and early diagnosis is fundamental as it permits to avoid major complications like peritonitis, embolisms, hemorrhage, and loss of the adnexa.

**Diagnostic Pathways**

The pelvic transvaginal US constitutes the first step in diagnostic pathways. The sonographic picture can present different aspects, depending on the degree of the torsion, from the associated adnexal pathology and, the time lapsed from the onset of the pathology, up to the moment of the US evaluation. In the initial phase, it is possible to observe ovaries that have increased in volume, with displaced follicles on the edge. At the stroma level, we can observe hyperechoic areas, sign of the bleeding infarction, associated with hypoechoic areas, which are an expression of the interstitial edema. The association between Doppler and ovarian morphology can improve the accuracy of the diagnosis. In 94% of cases, the absence of venous flow has an elevated value predicative of ovarian torsion; however, there are no unanimity of data on the role of pulsed Doppler or color Doppler, although in the presence of an enlarged ovary, edematous and painful, the absence of flow is strongly suggestive of adnexal torsions. In fact, the flow can be abnormal, as the blood supplied is assured by 2 vessels (ovarian and uterine), and the torsion can also be intermittent. A normal flowmetry report can be encountered during a phase of spontaneous distortion; therefore, the presence of flow does not exclude the diagnosis. Sonographically, the fallopian tube can present itself as a bruised formation elongated or fusiform adjacent to the ovary, where hyperechoic and hypoechoic areas are alternated. These latter represent the tortioned vessels of the peduncle. The color Doppler sometimes evidences the flow, where the vessels are not thrombosed. The artifact just described is not, in any case, always present, and it depends on the number of turns of the torsion. In the initial stage of the torsion of the vascular peduncle, there is a blockage of the lymphatic drainage, which determines the swelling of the stroma and subsequently an impairment of the venous flow or venous thrombosis. With the worsening of the interstitial edema, there is a progressive compression of the venous vessels that is reflected in the reduction of systolic peaks and then in the absence of diastolic flow. Following the compression due to edema also blocks the arteriosus flow. The use of MR is indispensable in all cases of acute abdomen where the US is not invalidating or to verify in a more appropriate manner the state of the ovarian torsion (Fig. 22). In addition, the MR, besides providing diagnostic information on the ovarian torsion, can facilitate the differential diagnosis with pathologic conditions, that can have a similar clinical picture or allow the diagnosis of pathologies responsible for the torsion, such

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**Figure 19** Ectopic abdominal pregnancy. Axial T2-weighted MR image of the pelvis (A) shows bilateral ovarian cyst (arrowheads) and fluid. Axial T1-weighted MR image at the same level (B) shows high signal fluid according to hematic fluid (star). Axial T2-weighted (C) and T1-weighted (D) MR images show a small mass on the right iliac fossa (arrows) according to ectopic abdominal pregnancy. In fact, the pregnancy is seen separate from the uterus, adnexa, and ovaries. Only after MR, β-HCG was evaluated, and it was considerably increased.
as ovarian neoplasia (Fig. 23). The MR picture varies according to the stage and if the torsions are complete or intermittent. In the initial phase, the dominant element, as already described for the US, and the edema, determined by the impeded venous outflow, which results in the increase of the ovarian dimension with increased signal in the T2-weighted sequence; the appearance of a bleeding infarction, in the subacute phase of the bleeding, is instead associated with the appearance of areas with elevated signals in the T1- and T2-weighted sequences caused by the presence of extracellular methemoglobin. US and MR should be preferred to CT in the diagnosis of ovarian torsion during pregnancy; however, it is possible that it is necessary to opt for CT under emergency, for example, in the presence of a massive hemoperitoneum.

Technical Pearls
The setting of the US is an important condition to avoid false negatives or false positives. The pulse repetition frequency, the scale of the colors, and the filters of the walls must be set up for a slow flow. The color gain must be regulated to the maximum possible having care that the image does not become vitiated from artefacts due to movement. In regards to the MR, a correct technical approach implies the acquisition
of axial, sagittal, and coronal images; these latter can reveal themselves useful for the identification of peduncle torsion with T1- and T2-weighted sequences and fat sat.81 The use of the fat saturation sequence is important for both the hemoperitoneum and the characterization of eventual ovarian masses. The use of IV contrast media facilitates the diagnosis of an ovary infarct. In fact, the absence of enhancement post-contrast medium of an ovary increased in size and of a thickened and edematous peduncle with ecstatic locoregional vessels, constitutes a diagnostic finding in itself.81 The prudent techniques for CT instead are the performance of precontrast medium scans and sagittal and coronal reconstructions for the study of the pelvic anatomy and the research of the peduncle torsion.

**Diagnostic Pitfalls**

The diagnosis of ovarian torsion can be difficult both for the clinical picture, more blurred, and the presence of pathologic conditions responsible for the torsion itself. The finding of an ovarian mass can corroborate the torsion diagnosis but can be misleading as a cyst of large dimensions can also be the cause of pain independently from the torsion of the peduncle. Even the histotype of the cyst can be a limiting factor in the correct diagnosis, for example, dermoid cysts of large dimensions can displace the tube and the remaining ovarian tissue, and for their anatomic-pathologic characteristics, they can be erroneously confused for an intestinal loop.83 The diagnosis, during the pregnancy, can be additionally complicated by the normal greater difficulty in sonographically visualizing the ovaries.83 The wrong diagnosis of ovarian torsion can occur more easily during the pregnancy and in the presence of additional gynecological pathologies like ovarian neoplasia, but also for the wrongly executed diagnosis of the examination. The quality of the US examination can also be vitiated from the nonavailability of transvaginal probes or the lack of use of the color Doppler technology. The failure to perform the fat-sat sequence in MR can impede the diagnosis of an adnexal mass just like for the failure of administration of contrast media can impede the identification of the absence of the strengthening of the ovarian torsion.

**Placenta Previa**

The placenta insertion is normally on the uterus walls, mainly the posterior one, far from the internal uterine orifice (OUI), and from the inferior part of the uterus that will become the inferior uterine segment. Placenta previa is a condition that occurs during pregnancy when the placenta is abnormally placed and partially or totally covers the OUI. The risk factors are maternal age (at age 35 years, it is 3 times
more frequent than at 25), number of pregnancies, cigarette smoking, multiple pregnancies, previous surgeries on the uterus, including cesareans (1 cesarean cut increases the risk 0.65%, 3 cesarean cuts by 2.2%, 4 or more cesarean cuts by 10%), and previous placenta previa (risk recurrence 4%-8%). Usually, from a clinical point of view, the placenta is classified in degrees from I to IV, as follows: a “totally central” placenta previa when the area of insertion completely covers the OUI (grade I), a “partial central” placenta previa when the OUI is only partially covered (grade II), a “marginal” placenta previa when the edge of the placenta is <3 cm from the edge of the OUI (grade III), and a “lateral” placenta previa when the edge of the placenta is between 3 and 5 cm from the OUI (grade IV). The risks of the placenta previa are both fetal and maternal. This condition is in fact associated to a series of fearsome and dangerous complications, such as premature birth, sudden and massive bleeding, and the detachment of the placenta. Failure to diagnose placenta previa may have grave consequences during the latter trimesters and at the time of delivery. The diagnosis of placenta previa can be made with certainty only after the 28th-30th week and before this period we speak of low insertion as the placenta can be traced. The relatively high incidence of placenta previa during the second trimester should not lead the radiologist to fail to diagnose this condition. Whenever the diagnosis is suspected in the second trimester, further evaluation is recommended. In nearly all cases, this evaluation involves repeat US during the third trimester.

Diagnostic Pathways

Transabdominal US is the test of choice to confirm placenta previa. When the OUI cannot be visualized or when the results are inconclusive, transperineal or transvaginal US is recommended as an adjunct. With a qualified operator, US is more than 95% accurate. Transvaginal US evaluation of the placenta has a 1% false-positive rate and a 2% false-negative rate. Hertzberg et al84 reported a 100% negative predictive value for transperineal US in a study of 164 patients. Transperineal studies have a negative predictive value of nearly 100% for this diagnosis. No increased risk of hemorrhage has been associated with transvaginal or transperineal US in this clinical setting. The major limitation of US in the diagnosis of placenta previa is related to the gestational age at diagnosis.

MRI has been used to evaluate placental location in a number of studies.85-88 Several series have shown that results are similar and possibly slightly better than those of US, but there are no large prospective MR studies in the literature for the diagnosis of placenta previa. The time required to arrange and perform an adequate examination may limit MR usefulness, particularly in the setting of acute maternal hemorrhage. The use of MRI in the diagnosis of placenta previa should be limited to a few specific cases, and MRI should be used only after US fails to provide adequate information.89

Technical Pearls

If the OUI can be visualized at US and if no placental tissue overlies it, placenta previa is excluded. However, an attempt must be made to identify the inferior-most aspect of the placenta and to determine the distance between it and the internal os. When the fetal head obscures a posteriorly positioned placenta or when the inferior placentental margin is not visualized with transabdominal imaging, a transvaginal or transperineal approach is nearly always adequate in revealing its position. Although diagnostic criteria may vary among institutions, any of the following findings excludes placenta previa: direct apposition of the presenting part of the fetus and the cervix without space for interposed tissue; the presence of amniotic fluid between the presenting part of the fetus and the cervix, without the presence of placental tissue; and a distance of >2 cm between the inferior aspect of the placenta

Figure 23  Satisfaction of search error in suspicious ovary torsion. Coronal (A) and sagittal (B) T2-weighted MR images show a complex mass, with fluid and solid components on the left ovary (borderline tumor), without ovary torsion signs. Coronal T2-weighted MR sequence (A) and axial T1 sequence (C) demonstrate germinal matrix hemorrhage extended to ventricular system (arrows), not reported. This is an observer error, and it is the result of diversion of the radiologist’s attention from a tumor by an eye-catching but unrelated finding.
and the internal cervical os on direct visualization. Care should be taken when diagnosing placenta previa during the second trimester (Fig. 24). This condition is reported to be 10-100 times as common in the second trimester as it is at term. Although the underlying physiology remains somewhat controversial, the disparity remains a fact. When placental tissue lies near or over the internal os in the second trimester, repeat imaging should be performed at a later date to confirm the diagnosis.

Usually, the placenta is relatively homogeneous in MRI. Its signal intensity on T1-weighted spin-echo images is low and slightly higher than that of the myometrium. On T2-weighted spin-echo images, placental tissue has high signal intensity, and it is clearly distinguishable from the adjacent fetus, uterus, and cervix. Sagittal images best demonstrate the placental position in relation to the internal cervical os (Fig. 25). Occasionally, endometrial veins may be seen at the margins of the placenta. Normal physiological placental calcifications, which occur during late pregnancy, usually are not seen on MRIs.

Diagnostic Pitfalls

The conditions that are most commonly misdiagnosed as placenta previa are an overdistended bladder and myometrial contractions. Overdistention of the maternal urinary bladder places pressure on the anterior aspect of the lower uterine segment, compressing it against the posterior wall and causing the cervix to appear elongated. Thus, a normal placenta may appear to overlie the internal os. The cervix should be no longer than 3-3.5 cm during the third trimester. If the cervical length exceeds 3.5 cm or if a falsely elongated cervix is suspected, further imaging should be performed after the patient empties her bladder. Because transvaginal and transperineal imaging is performed when the patient's bladder is empty, this pitfall should occur only rarely.

During a myometrial contraction, 2 situations that mimic placenta previa may occur: first, the wall of the uterus may thicken and imitate placental tissue; second, the lower uterine segment may shorten and bring the inferior edge of the placenta into contact with the internal cervical os, creating a condition that mimics placenta previa. To avoid this pitfall, a contraction should be suspected if the myometrium is thicker than 1.5 cm. Findings from repeat imaging performed after 30 minutes should be sufficient to exclude this condition. Care should be taken not to mistake a more serious situation, such as placental abruption or placenta accreta, for placenta previa, because the management of these conditions is different. In addition, the radiologist must avoid satisfaction-of-search errors. The possibility of one of these diagnoses complicating placenta previa must be excluded. The likelihood of congenital anomalies and transverse fetal positioning is slightly higher in patients with placenta previa than in others. Special care should be taken to document such findings.

MR false-positive findings may result from myometrial contraction in the lower uterine segment at imaging. Al-
though the placental margin remains distinct from the contracted muscle and the internal cervical os, the distance between the placental margin and the os may decrease, leading to a false diagnosis of a low-lying placenta. In extreme cases, the edge of the placenta might come into contact with or even overlie a portion of the internal cervical os, and thereby mimic placenta previa. Moreover, a finding of placenta previa should elicit a detailed evaluation for placenta accreta, including color Doppler imaging and a transvaginal examination. Placenta accreta encompasses various types of abnormal placentation in which chorionic villi attach directly to or invade the myometrium. Placenta accreta is a significant

Figure 26  Abdominal pain in suspicious ovary torsion. Axial T2-weighted (A) and coronal steady-state (B) images show a huge exophytic leiomyoma, which is a common cause of an apparent adnexal mass at sonograph. In the context of the mass, there are areas of cystic degeneration. In this patient, T1-weighted sequence was not performed, and it was not exclude a red degeneration of the leiomyoma.

Figure 27  Fibroids undergoing hemorrhagic degeneration during pregnancy. Axial fat saturation T1-weighted (A) and sagittal T2-weighted (B) images show a leiomyoma with peripheral (arrows) high signal intensity according to red degeneration. Axial fat saturation T1-weighted (c) and axial T2-weighted (d) show a leiomyoma with diffuse high signal intensity on T1, according to red degeneration.
cause of maternal morbidity and mortality and is now the most common reason for emergent postpartum hyste-
tomy. US is the diagnostic standard, and routine US exami-
nation at 18-20-weeks' gestation affords an ideal opportunity
to screen for the placenta accrete. The most useful MR find-
ings for placenta accrete are uterine bulging, heterogeneous
signal intensity within the placenta, and dark intraplacental
bands on T2-weighted images.

Fibroids

Fibroid-related pain in pregnancy may be because of the
rapid growth, torsion, or degeneration of the fibroids. The
excess estrogen triggers the fibroid to grow faster than its
blood supply can support it. The lack of oxygen and nutrients
causes the fibroid to turn red and break down. Fibroid de-
generation may cause focal pain, tenderness on palpation,
low-grade fever, and leukocytosis. Most often, signs and
symptoms abate within a few days, but inflammation may
stimulate labor.

Diagnostic Pathway

In pregnant patients with abdominal pain secondary to fi-
broid degeneration, the diagnosis can be made on sonogra-
phy by identifying point tenderness when the probe is place
over the fibroid. In complicated cases, MRI can be helpful in
making the diagnosis.

Technical Pearls and Diagnostic Pitfalls

Exophytic leiomyomas are a common cause of an apparent
adnexal mass at sonography (Fig. 26). MR is superior to
sonography in differentiation leiomyomas from other
masses. Occasionally during pregnancy, leiomyomas un-
dergo spontaneous hemorrhagic infarction, known as
“red degeneration.” Fibroids undergoing hemorrhagic de-
generation during pregnancy typically exhibit peripheral
(Fig. 27A) or diffuse (Fig. 27B) high signal intensity on
T1-weighted imaging and variable signal intensity on T2-
weighted imaging. The hyperintense rim on T1-
weighted imaging may correspond to obstructed veins at
the periphery of the mass. Edema can cause diffuse in-
creased signal intensity of uterine fibroids on T2-weighted
imaging and may antedate degeneration.

Acknowledgments

Thanks to Stefano Caprasecca, Dino D’Amico and Serena
Cecchini.

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