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PRACTICE POINTER

Making decisions about radiological imaging in pregnancy

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What you need to know

- Consider imaging when the risk of potential pathology outweighs the potential risk of imaging
- In radiography and computed tomography (CT), the risk of childhood cancer induction is very low if imaging is above the diaphragm or below the knee. If intravenous contrast agent is used in CT, test thyroid function in the child after birth via heel prick
- Ultrasound and magnetic resonance imaging have no known risks for the fetus, although they have theoretical risks. Avoid contrast agents for both these modalities

Globally, ultrasound has been used in pregnancy for decades. The use of other imaging modalities—such as plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI)—in pregnancy is increasing.[1] Imaging plays an important role in the investigation of many conditions in pregnancy, but also has potential to cause harm. Concerns about harm to the fetus and mother can make decisions to image difficult for patients and clinicians. However, risk is often lower than expected and, especially in many acute situations, is outweighed by the benefit.

This article outlines the potential fetal and maternal risks from commonly used imaging modalities. We also present frequently encountered emergency clinical scenarios, along with imaging suggestions for each situation, with the aim of enabling referring clinicians and patients to make informed shared decisions.

Imaging modalities and types of radiation covered include:

- Ultrasound—uses high frequency sound to produce images
- Ionising radiation—uses high energy electromagnetic radiation to produce images. X rays (used in plain radiography and CT) and gamma rays (used in nuclear medicine studies) are the most commonly used forms of ionising radiation in medical imaging.
- MRI—uses strong magnetic fields and radio waves to produce images.

The following aspects are beyond the scope of this article:

- Elective scenarios which could potentially wait until after pregnancy; however, the principles discussed can be applied to all pregnant patients
- Issues that are primarily the role of radiology departments—eg, dose modification techniques, and prevention or management of inadvertent fetal imaging (when patients are unaware they are pregnant)
- Postpartum imaging and imaging in patients who are breastfeeding.

What is the evidence?

Evidence used to create this article includes experimental animal studies, observational epidemiological studies on human subjects, and, in the case of ionising radiation, studies from atomic bomb survivors in Japan.[2-6] Most human studies are retrospective.

What potential risk does imaging in pregnancy pose to the fetus?

Different imaging modalities have different effects on human tissues, and as such, pose different risks (and levels of risk) to the fetus (table 1). High dose ionising radiation such as CT is generally of more concern than ultrasound, MRI, and low dose ionising radiation such as plain radiography.

Table 1 | Fetal risks associated with, and guidelines for, the use of specific imaging modalities in pregnancy

Modality	Consideration	
Ultrasound	Potential indications in pregnancy	Obstetric imaging Suspected acute abdominal/pelvic pathology Heart imaging (echocardiography)
	Evidence based summary of risk	No evidence of adverse maternal, fetal, perinatal, or childhood outcome.[2]* Theoretical risk from heating and movement effects[7 8] but no adverse outcomes have been found from these in human studies
	IV contrast use (microbubbles)	Used rarely (some echocardiography, characterisation of liver and renal lesions). Microbubbles can burst and cause cavitation. They enter the placenta, and placental damage risk has not been well investigated[9]
	Recommendations	Generally safe, but keep as low as reasonably achievable principle[7 8]: - only request if clinically indicated Generally avoid ultrasound contrast unless benefits clearly outweigh the risks[10]
Ionising radiation	Potential indications in pregnancy	X rays: Plain radiographs—eg, chest radiographs for acute respiratory presentations and extremities in trauma CT—eg, CT head in suspected intracranial haemorrhage, CT pulmonary angiography (CTPA) in suspected pulmonary embolism, and CT abdomen in trauma Gamma rays: ventilation/perfusion (VQ) scans in suspected pulmonary embolism
	Evidence based summary of risk	Fetal malformation, growth restriction, intellectual disability, or death, should not occur with radiation levels used in diagnostic imaging.[7 11] UK guidelines suggest this threshold is 100 mGy[11]; US guidelines suggest 50 mGy.[7] Theoretically, cancer induction can occur with any dose of ionising radiation, and as such no threshold exists below which this cannot occur.[11] Risk is dependent on dose and body part imaged. See table 2 for childhood cancer risk with ionising radiation
	IV contrast use (iodinated contrast)	Used in most body imaging including CTPA and CT abdomen studies. Not routinely used in brain imaging unless vascular assessment required (eg, CT venogram and angiogram studies). Contrast crosses the blood-placental barrier but no evidence suggests that IV CT contrast administered at any time in pregnancy causes harm to the fetus.[10] A theoretical risk exists for neonatal hypothyroidism[12]
	Recommendations	Always keep doses as low as reasonably achievable. Low fetal dose procedures (eg, radiography and CT above the diaphragm or below the knees) pose minimal risk of childhood cancer induction— <1 in 10 000-100 000—and can be justified when clinically indicated. Only consider higher fetal dose procedures (eg, CT which covers the pelvis) when information cannot be obtained without ionising radiation, and if serious detriment to the patient's health is likely without the scan. If performed, fetal dose should not exceed 50-100 mGy. See table 2 for more detail about dose and fetal risk. IV contrast can be used if clinically indicated—if used, screen babies for neonatal hypothyroidism in their first week of life[10 13]**

Table 1 | Fetal risks associated with, and guidelines for, the use of specific imaging modalities in pregnancy *(Continued)*

Modality	Consideration	
MRI	Potential indications in pregnancy	Brain imaging Fetal imaging Acute abdominal pain
	Evidence based summary of risk	No conclusive evidence that MRI causes fetal harm.[7 14 15] Theoretical risks of fetal hyperthermia[5] and inner ear damage[6] can be mitigated by scanner modifications[15]
	IV contrast use (gadolinium based contrast)	Contrast crosses the blood placental barrier. Limited evidence shows that MRI contrast use in pregnancy is associated with "a broad set of [neonatal] rheumatological, inflammatory, or infiltrative skin conditions" and of stillbirth or neonatal death[16]
	Recommendations	MRI can be considered safe in pregnancy. Some bodies, such as the UK government's Medicines and Healthcare Products Regulatory Agency, advise caution in scanning in the first trimester (though it is advised this can be done when the benefits outweigh the risks).[15] Others, such as the American College of Radiologists, suggest that patients in the first trimester of pregnancy should not be treated differently from those in later stages of pregnancy.[14] Generally avoid IV gadolinium unless it will change management during pregnancy or no method of obtaining information is available[10 17]

* Meta-analysis cited found a weak association between ultrasound exposure and non-right handedness in boys, though not when boys and girls were analysed together.

** Already offered to all newborns in Europe, Australia, New Zealand, and North America to assess for congenital hypothyroidism.

Is there a role for abdominal shielding?

Abdominal lead shielding was historically used for ionising radiation that did not directly expose the fetus (eg, chest radiography and CT pulmonary angiography (CTPA)). However, as most of the fetal dose in these investigations is from internal (rather than external) scatter, abdominal shielding is unlikely to be of benefit.[18] Additionally, if the shield is inadvertently in the field of view during the scan, automatic exposure control can cause increased dose.[18]

Guidelines from the American Association of Physicists in Medicine[19] and British Institute of Radiology[20] suggest avoiding routine shielding, but recommend considering it case by case if it offers patient reassurance after adequate counselling about the above.

When does imaging pose a maternal risk?

Ultrasound

A meta-analysis performed on behalf of the World Health Organization found no evidence of adverse maternal outcome following ultrasound in pregnancy and it can be considered safe.[2]

Ionising radiation

Breast tissue is particularly susceptible to the effects of ionising radiation[21] and pregnant (and breastfeeding patients) are theoretically at increased risk because breast tissue is actively undergoing glandular proliferation.[18] However, a retrospective population based cohort study with a short term follow-up period (<12 years) did not show an increased risk of breast cancer in patients exposed to CT chest or VQ scanning in pregnancy.[22]

MRI

Usual MRI safety considerations for all patients apply. In pregnancy, the relatively long scan times (20 minutes to one hour) and claustrophobia may be difficult, particularly in late pregnancy. Consider reduced scan times and alternative (eg oblique) positioning.

Difficulties in interpretation

False negative and false positive findings can occur in pregnancy because of altered anatomy and physiology. For example, haemodynamic circulation causing difficulties in pulmonary artery opacification on CTPA,[23] and displacement or compression of structures by the gravid uterus can make visualising suspected acute abdominal pathology on ultrasound difficult.[24]

Incidentalomas

As with all patients, imaging presents a risk of detecting incidental findings, which may lead to further investigations and may increase patient anxiety unnecessarily.[25]

How are shared decisions made?

For ultrasound, MRI, and low dose ionising radiation (tables 1 and 2) discussion may be relatively straightforward.

Table 2 | Typical fetal doses and risks of childhood cancer for some common diagnostic ionising radiation modalities used in pregnancy

Examination	Typical fetal dose (mGy) from a single scan	Risk of childhood cancer per examination
Radiography Teeth Neck Chest Extremity Mammography	0.001-0.01	<1 in 1 000 000
CT Chest Pulmonary angiogram	0.01-0.1	1 in 1 000 000 to 1 in 100 000
Radiography Abdomen Pelvis Hip **CT** Chest and liver **Nuclear medicine** VQ scan	0.1-1.0	1 in 100 000 to 1 in 10 000
Radiography Lumbar spine **CT** Lumbar spine Abdomen (not pelvis)	1.0-10.0	1 in 10 000 to 1 in 1 000
CT Abdomen and pelvis **PET/CT** Whole body	10.0-50.0	1 in 1 000 to 1 in 200

Based on data summarised by the UK's Health Protection Agency, The Royal College of Radiologists, and The Royal College of Radiographers.[11]

Doses apply to early stages of pregnancy when the fetus is small.

Risk of childhood cancer has been rounded up to 1 in 10 000 per mGy.

For comparison, natural childhood cancer risk is ~1 in 500.

For techniques that involve exposure of the fetus or breast tissue to higher doses (eg, some plain radiography, CT), we suggest the following:

- Explain why imaging is being suggested and how it will change management for the patient (and, if appropriate, the fetus). Explain what may happen if no imaging is done—eg, the risk of missing serious pathology, acknowledging that this may be difficult to quantify.
- Give an estimated numerical risk of harm (table 2) in relative terms—eg, the background risk of childhood cancer is approximately 1 in 500, so an additional risk of 1 in 500 doubles the risk the baby will later develop childhood cancer—ie, "for every 500 times this scan is done in pregnancy, theoretically, one child would develop a cancer that they would not have developed otherwise."
- Provide context—eg, exposure to the fetus from background radiation is approximately 1 mGy, and radiation exposure from a transatlantic flight is 0.01 mGy[26]
- Offer patient information leaflets if available (see below).

The Royal College of Obstetricians and Gynaecologists offers general advice to patients and clinicians on discussing risk that can be applied to imaging in pregnancy.[27 28]

Is written consent needed?

Consent for imaging processes vary. The ACR suggests that consent can be obtained in both verbal and written forms but in either case should be documented. ACR offers a sample patient consent form in its guidelines.[29]

Common clinical scenarios

Trauma

A 27 year old woman is brought to the emergency department by ambulance following a high speed road traffic collision. She is 30 weeks pregnant.

She has a Glasgow coma scale score of 15, pulse rate 125 beats/min, blood pressure 120/70 mm Hg, and respiratory rate 25 breaths/min.

She has pain in the left lower chest wall and left flank and left flank guarding and bruising. She says her baby is moving normally and the obstetric team has no immediate concern about the fetus. The surgical team is called and imaging is considered. The patient wants to know about risks to her baby from CT scanning.

Trauma is the leading non-obstetric cause of maternal mortality and can also cause fetal loss, so early identification of injury is important.[30] Consider radiology when the risk from trauma is likely to be higher than the risk from imaging.

Chest radiography and focused assessment with sonography in trauma may help to rule in some injuries (eg, pneumothorax, large volume haemoperitoneum) and expose the fetus to minimal or no radiation. However, these modalities may not rule out potentially life threatening injury, which could put the patient and fetus at risk (eg, active bleeding, organ injury, fractures).

When potentially life threatening thoracic or abdominal injury is suspected, CT scan is the imaging modality of choice and intravenous (IV) contrast is usually required (fig 1).

Fig 1 | CT scan of the abdomen and pelvis (with IV contrast) of a pregnant patient involved in a high speed road traffic accident. (a) Axial image (soft tissue windowing) showing the gravid uterus and anterior placenta (arrows), (b) axial image (bone windowing, arrows), (c) coronal image (bone windowing) showing a right sacral fracture (arrows)

Discuss with the patient the risk of missing life threatening pathology versus the relatively small risk of childhood cancer induction from CT. Table 2 gives approximate risks (note, doses, and risk in table 2 are for single scans, but trauma protocols can

involve dual phase scanning[31]). Offer reassurance that the fetus is not at definitive risk from any IV contrast administration, but because of the theoretical risk of hypothyroidism, neonatal heel prick is advised (table 1).

Once life threatening injury to the patient is excluded, consider obstetric ultrasound to look for fetal, placental, and uterine injury.[30]

Headache

A 35 year old woman attends an out-of-hours GP service with headache and vomiting that started suddenly, 24 hours earlier. She is 17 weeks pregnant and has no headache history. She has diplopia but no fever or meningism. Vital observations and urine dipstick are unremarkable. The GP recommends urgent assessment in the emergency department and advises that this will likely include imaging. The patient wishes to discuss imaging options.

Headache in pregnancy is common and usually the result of primary headache disorders (eg, tension headache or migraine).

After 20 weeks' gestation, pre-eclampsia is also a common cause and associated with hypertension with or without proteinuria.[32]

Consider urgent radiological investigations if there is clinical suspicion of a life threatening diagnosis (eg, subarachnoid haemorrhage, venous sinus thrombosis).

CT is quick, widely available, can readily detect acute haemorrhage, and post contrast imaging is possible. MRI is more sensitive than CT for detecting most intracranial pathology; however, it is slower, less readily available, more prone to artefact, and post contrast imaging (using gadolinium) is generally not recommended in pregnancy[10 17] (table 1).

If CT is clinically indicated and would be the usual first choice in a non-pregnant patient, the authors recommend not delaying CT (ie, avoid considering MRI as first line purely on the basis of fetal risk).

Advise the patient that the radiation dose to the fetus from CT scanning of the head is negligible (table 2).[11]

If CT is negative, further investigation with MRI, post contrast CT, or lumbar puncture may be required, depending on the suspected diagnosis.

Suspected pulmonary embolism

A 32 year old woman attends the emergency department following sudden onset chest pain and dyspnoea six hours earlier. She is 25 weeks pregnant. She has no relevant medical history, fever, cough, or alteration in her sense of taste or smell.

Her pulse rate is 105 beats/min and her respiratory rate 18 breaths/min. Other observations, examination, electrocardiogram, routine blood tests, and chest radiograph are normal. The clinical team suspects pulmonary embolism, and imaging is discussed. The patient is concerned about implications for her baby. She asks, "What difference will a scan make if I have a blood clot in my lungs?"

The risk of missing pulmonary embolism or of anticoagulating a patient without pulmonary embolism puts the patient (and therefore fetus) at risk of illness or death, so imaging is recommended.[35]

If the patient has clinical signs of deep vein thrombosis (DVT), perform lower limb vein ultrasound.[36 37] In the absence of signs of DVT, guidelines for imaging of suspected pulmonary embolism in pregnancy are conflicting.[38] Some suggest lower limb vein ultrasound to avoid ionising radiation. Others advise doing this only if the patient also has clinical signs of DVT.

Direct imaging is most commonly performed with CTPA (fig 2) or VQ scanning. Choosing between these studies is controversial and varies between institutions because each modality has relative risks and benefits (table 3).

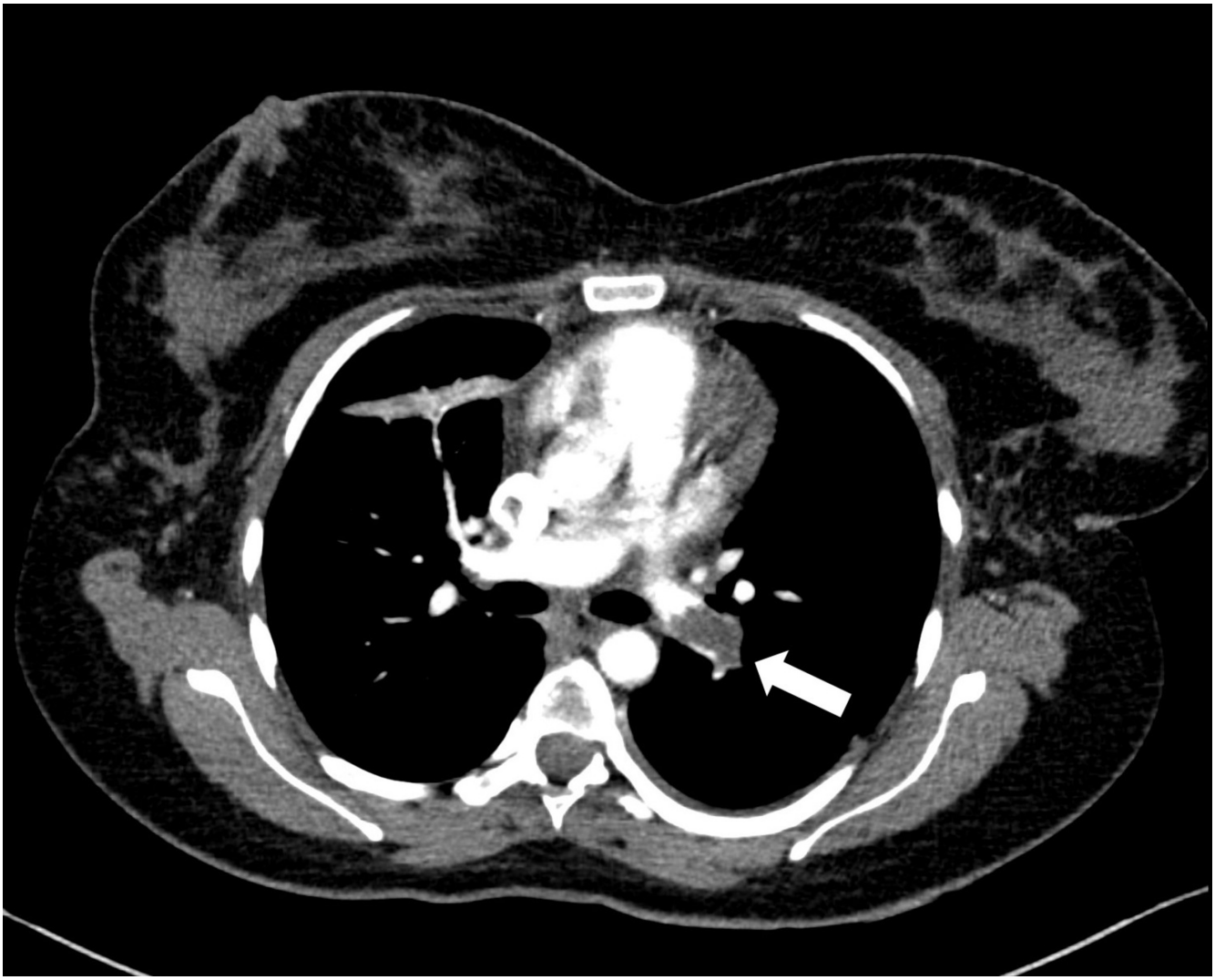

Fig 2 | CTPA in a patient in the first trimester of pregnancy showing acute pulmonary embolism in the left pulmonary artery (arrow). Pregnancy makes the breast tissue dense and glandular (ie, at increased risk from ionising radiation)

Table 3 | Imaging for suspected pulmonary embolism in pregnancy

Modality	Fetal dose[11]*	Maternal breast dose[39]*	Availability	Use in presence of other lung pathology[39]	Likelihood of non-diagnostic result[40]	Other considerations
CTPA	Low. May be lower than VQ. 0.01-0.1 mGy (1 in 1 000 000 to 1 in 100 000 risk of childhood cancer)	May be higher than VQ 10-60 mGy	Good—common test performed widely	Advised	12%; 95% confidence interval (CI) 8 to 17	IV contrast used (table 1)
VQ	Low. May be higher than CTPA 0.1-1 mGy (1 in 100 000 to 1 in 10 000 risk of childhood cancer)	May be lower than CTPA 0.98-1.07 mGy	May be limited, especially out of hours	Not advised	14%; 95% CI 10 to 18)	Perfusion scan can be performed first. If normal, ventilation scan is not needed

* A Cochrane review41 and further meta-analysis40 pooled data regarding maternal and fetal doses for CTPA and VQ and advised caution in interpreting results of studies because of a lack of high quality data.

Reassure the patient that whichever modality is used, the risks of harm to the pregnant woman and fetus are likely to be less than those of missing a pulmonary embolism.

Acute abdominal pain

A 30 year old woman attends the emergency department with right iliac fossa pain which started in the mid abdomen. She is 30 weeks

pregnant. On examination, she has tenderness and guarding in the right iliac fossa. Blood tests show elevated white cell count and C reactive protein levels. Urine dipstick is normal. Acute appendicitis and adnexal torsion are considered the most likely differential diagnoses. The patient asks, "Do I need an MRI? Isn't ultrasound good enough?"

Early diagnosis of acute abdominal or pelvic pathology can prevent maternal and fetal harm. The risk of not treating some conditions (eg, acute appendicitis or adnexal torsion) while difficult to quantify, is likely to be higher than the risk of imaging.

Ultrasound is safe in pregnancy. It is often the first modality used for abdominal and pelvic pain in a non-emergency situation. However, its usefulness is dependent on the skill or experience of the operator and views of deep structures can be poor owing to anatomical displacement. Ultrasound for acute appendicitis has 50-100% sensitivity and 33-92% specificity in pregnant patients.[42]

MRI (fig 3) is potentially more accurate[42]—eg, for acute appendicitis, sensitivity is 92% and specificity 98%.[43] It is, however, more time consuming and not as readily available as ultrasound, particularly out of hours.

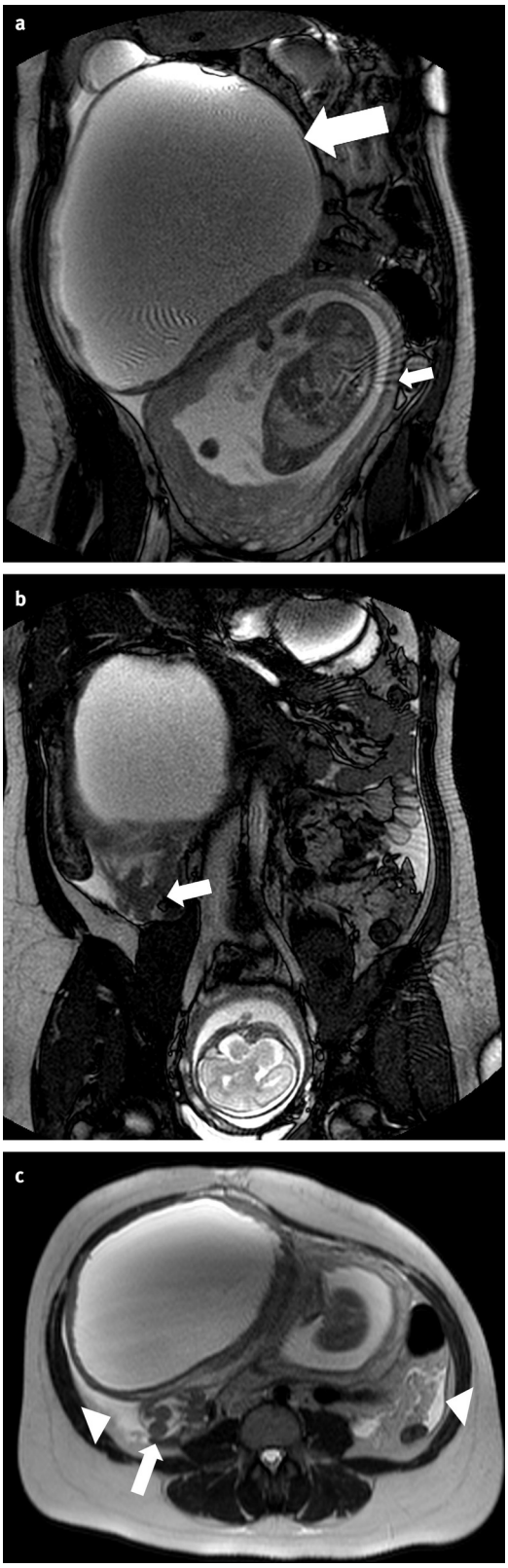

Fig 3 | MRI in a pregnant patient showing right adnexal torsion. (a) and (b) Coronal balanced fast field echo images, (c) axial T2 weighted images. The patient has a right sided abdominal mass with a thick irregular wall and central fluid signal (large arrow in (a)) and abdominal free fluid (arrowheads in (c)), both of which had been detected on ultrasound. The known intrauterine pregnancy is also shown (small arrow (a)). An additional finding on MRI, not detected on ultrasound, was the twisted adnexal pedicle (arrows in (b) and (c)) connecting the uterus to the mass, confirming the diagnosis of adnexal torsion for which surgery in pregnancy was required

If MRI is being considered, advise patients that there is no known harm to the fetus (table 1) but that scan times are at least 20 minutes (potentially longer) and scanners are small, which may be uncomfortable. Avoid IV contrast (table 1).

If MRI is not available, CT can be considered but involves pelvic irradiation, so only if there is no alternative. The risks are discussed above, under "Trauma."

Education into practice

- How often do you assess whether patients of pre-menopausal age could be pregnant before requesting imaging?
- How do you communicate imaging risk to pregnant patients? What alternatives to imaging do you offer?
- What local protocols and pathways does your institution use when imaging pregnant patients? If no pathway is available for imaging suspected pulmonary embolism in pregnancy based on local availability of radiological services, how might you consider implementing one?

How patients were involved in the creation of this article

EB is a patient representative in the Liverpool Babies Patient and Public Involvement and Engagement Group. She provided a patient perspective on imaging in pregnancy. This included the discussion surrounding how to discuss risk with patients and the use of straightforward terminology, without being patronising. She produced the "Information for Patients" section of the article.

The article was also reviewed by an external patient representative. As a result, the language was worded to ensure clear information to the reader, acknowledging that the reader (be they medical professional or patient) may not be familiar with some radiological and other technical terms.

How this article was created

The authors searched for UK and international guidelines (from both radiological and obstetric and gynaecological societies and faculties) regarding imaging pregnant patients with ultrasound, ionising radiation, and MRI. Guidelines for imaging in specific conditions were also reviewed.

The authors performed a literature search of patient information leaflets discussing the subjects relevant to the study—imaging in pregnancy and the investigation of specific conditions in pregnancy.

Information resources for patients

Radiological practice may vary in different institutions, so some of the information in these resources may not apply to all situations.

Ionising radiation

- X ray and nuclear medicine:
  - The Heath Physics Society (a non-profit scientific professional organisation based in the US) offers information for patients about how radiation can affect them. The section on their website "The Unborn Child" gives in depth information for pregnant patients, focussing on x ray and nuclear medicine: https://www.radiationanswers.org/radiation-and-me/radiation-reproduction/unborn-child.html
- X ray and CT:
  - This is a patient information leaflet produced by the New South Wales Agency for Clinical Innovation in Australia. It includes specific information about the small risk of ionising radiation to the fetus and relates this to background radiation risk. This leaflet is also available in Arabic, Chinese, Greek, Korean, and Vietnamese: https://aci.health.nsw.gov.au/__data/assets/pdf_file/0003/273450/risk-of-x-rays-and-ct-scans-in-pregnancy-patient-factsheet-o.pdf
- CT:
  - *RadiologyInfo* is a public information website developed and funded by the *Radiological Society of North America* and the *American College of Radiology*. *This webpage gives quick, easy-to-read, basic information about CT in pregnancy:*https://www.radiologyinfo.org/en/info/safety-ct-pregnancy

MRI

- NHS Greater Glasgow and Clyde Heath Board in the UK has produced a patient information leaflet regarding MRI in pregnancy. This is a simple one page guide reassuring patients that MRI likely poses no risk to the fetus: https://www.mriphysics.scot.nhs.uk/wp-content/uploads/2019/12/Info_for_pregnant_patients_final_v_Dec_19.pdf

Investigation of suspected venous thromboembolism

- Oxford University Hospitals NHS Foundation Trust and Royal Devon and Exeter NHS Foundation Trust in the UK have produced comprehensive patient information leaflets about the investigation of suspected VTE. Both give context of background radiation when explaining the risk of the tests. Local practice will vary (particularly with the availability of nuclear medicine scanning) and as such this should be taken into account when considering the use of these patient resources:
- https://www.ouh.nhs.uk/patient-guide/leaflets/files/61547Pclots.pdf
- https://www.rdehospital.nhs.uk/media/wufp4pix/patient-information-leaflet-scanning-for-suspected-pulmonary-embolism-and-deep-vein-thrombosis-pe-dvt-in-pregnancy-and-the-postnatal-period-rde-20-083-001.pdf

Understanding risk

- The Royal College of Obstetricians and Gynaecologists has produced a patient information leaflet explaining how risk is explained in healthcare. This is a generic article, rather than pregnancy specific, but pregnant patients may find some of the themes useful:
- https://www.rcog.org.uk/for-the-public/browse-all-patient-information-leaflets/understanding-how-risk-is-discussed-in-health-care/

Contributorship and the guarantor: RW conceived the article. RW and AS are guarantors. EB and RW wrote the "Information resources for patients" section. RW, AS, and BH wrote the rest of the article.

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Competing interests: AC has received payment from Roche for giving an invited talk about the role of blood biomarkers sFlt-1/PlGF in predicting fetal growth restriction at a lunchtime symposium at an international conference in 2019. He received travel and accommodation expenses and an honorarium for his lecture. RW, BH, and EB declare no competing interests.

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