

CAR/CETARS/CSAR Practice Guideline on Imaging the Adult Patient With Right Lower Quadrant Pain

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Abstract

In 2023, the Canadian Society of Abdominal Radiology (CSAR) and Canadian Emergency, Trauma, and Acute Care Radiology Society (CETARS) received Canadian Association of Radiologists (CAR) member feedback that there was an unmet educational need for guidance in the imaging investigation of right lower quadrant (RLQ) pain. Members requested specific guidance on how to handle controversial scenarios including which test to order when, specifics of imaging protocols, and managing pregnant patients who have RLQ pain—all from a Canadian perspective. After conducting an exhaustive literature review, the working group agreed that a Canadian-specific set of guidelines was warranted. The management recommendations presented in this guideline were discussed as a group to achieve expert consensus. As the workup for RLQ pain can vary considerably in the paediatric population, the scope of this paper was restricted to adults (18 years of age or older). Whenever possible, the best evidence was used to inform the clinical guidance, and where gaps existed, the guidelines reflect consensus among experts in the field. The result is a framework to aid in this process of managing patients with RLQ pain across various clinical scenarios while addressing current questions and controversies, particularly those most relevant to the Canadian healthcare system.

Résumé

En 2023, la Société canadienne de radiologie abdominale (CSAR) et la Société canadienne de radiologie d'urgence, de traumatologie et de soins actifs (CETARS) ont reçu des commentaires de la part de membres de l'Association canadienne des radiologistes (CAR). Ceux-ci considèrent qu'il existe un besoin éducatif non satisfait en matière d'orientation liée aux examens par imagerie de la douleur abdominale dans le quadrant inférieur droit (RLQ). Les membres ont demandé des conseils précis sur la manière de traiter des scénarios controversés, notamment à propos du choix du test à prescrire, des spécificités des protocoles d'imagerie et de la prise en charge des patientes enceintes souffrant de douleurs dans le RLQ, le tout d'un point de vue canadien. Après avoir procédé à une analyse exhaustive des articles scientifiques publiés,

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le groupe de travail a convenu que l'élaboration d'un ensemble de lignes directrices propres au Canada était justifiée. Les recommandations de prise en charge présentées dans ces lignes directrices ont été discutées en groupe afin qu'un consensus d'experts soit obtenu. Comme le bilan diagnostique de la douleur dans le RLQ peut varier considérablement chez les enfants, le champ d'application de ce document a été limité aux adultes (personnes âgées de 18 ans ou plus). Dans la mesure du possible, les meilleures données probantes ont été utilisées afin d'étayer les orientations cliniques et, en cas de lacunes, les lignes directrices reflètent le consensus des experts dans ce domaine. Il en résulte un cadre visant à faciliter le processus de prise en charge des patients souffrant de douleur dans le RLQ, et ce, selon divers scénarios cliniques. De plus, des questions et controverses actuelles y sont abordées, en particulier celles qui sont les plus pertinentes pour le système de soins de santé canadien.

Keywords

right lower quadrant pain, guidelines

Introduction

In 2023, the Canadian Society of Abdominal Radiology (CSAR) and Canadian Emergency, Trauma, and Acute Care Radiology Society (CETARS) received Canadian Association of Radiologists (CAR) member feedback that there was an unmet educational need for guidance in the imaging investigation of right lower quadrant (RLQ) pain. There were specific requests to provide recommendations on how to handle controversial scenarios such as which test to order when, specifics of imaging protocols, and managing pregnant patients who have RLQ pain—all from a Canadian perspective. The CAR Right Lower Quadrant Pain Working Group was formed to address this request and consisted of members of the CSAR and the CETARS from a variety of practice settings across Canada. The group conducted an exhaustive literature review, including a review of the American College of Radiology Appropriateness Guidelines, and concluded that a Canadian-specific set of guidelines was warranted.¹ All management recommendations were discussed as a group to achieve expert consensus. As the workup for RLQ pain can vary considerably in the paediatric population, the scope of this paper was restricted to adults (18 years of age or older).²

While the recommendations presented are based on the best available scientific evidence, there are some significant gaps in the literature, particularly pertaining to the Canadian experience and resource limitations. As a result, these guidelines reflect consensus recommendations rather than a fully evidence-based standard of care.

Scope of the Problem and Overview

Approximately 5% to 10% of emergency department (ED) patients present with abdominal pain, and almost half of those patients will have RLQ pain.^{3,4} Just under half of all patients with abdominal pain in the ED will undergo ultrasound (US) or computed tomography (CT), and the use of diagnostic imaging in this setting increased 6-fold from 1992 to 2007.³

Due to the availability of diagnostic imaging, 8 out of 10 patients presenting to the ED with abdominal pain receive a specific diagnosis.³

There are several potential causes of RLQ pain, and these can be categorized by organ system (Table 1).^{1,2,5-7} In female patients, it is vital for the ordering clinician to perform a comprehensive physical examination in order to differentiate pelvic from RLQ pain, as this will significantly impact the choice of investigations. Key clinical information should be readily available so that the consultant radiologist may triage patients and select the appropriate study and protocol. Requisitions should indicate the patient's age, sex (and, if applicable, pregnancy status), the location of the pain (including if it has migrated), relevant past medical and surgical history, other ancillary findings such as fever, elevated white blood cell count, and urinalysis results.

The remainder of the paper will provide guidance on the following: (1) selecting the best imaging modality for specific clinical scenarios, (2) recommended imaging protocols, and (3) specific guidance for imaging pregnant patients.

The authors would like to express their acknowledgement and respect for all gender identities while clarifying the terminology used. In this article, the term "female" is employed to signify patients with internal gynaecologic organs for ease of reference, with no intent to disrespect or overlook individuals across the diverse spectrum of gender identities.

What to Order When

Imaging patients with RLQ pain should lead to a confident early and definitive diagnosis and help eliminate alternative diagnoses with high accuracy. There is an increased cost and ED length-of-stay when more than one imaging modality is used,⁸ and it is thus ideal to perform the highest-yield test to make the correct diagnosis first, without further testing. A rapid and accurate diagnosis can prevent substantial morbidity and reduce overall health system costs. After-hours availability of skilled US technologists and radiologists may be

Table 1. Causes of Right Lower Quadrant Pain by Organ System.

Organ system	Potential diagnoses
Intestinal	Appendicitis
	Appendiceal mucocele or neoplasm
	Right-sided colonic or small bowel diverticulitis
	Colon or small bowel carcinoma
	Bowel obstruction
	Hernia
	Inflammatory bowel disease or other enteritis/colitis
	Intussusception
	Cecal volvulus
	Intestinal ischaemia
	Neutropenic enterocolitis
	Fecal retention
	Irritable bowel syndrome
	Urinary
Pyelonephritis/ureteritis	
Gynaecologic	
	Ovarian torsion
	Ovarian cyst
	Ectopic pregnancy
	Endometriosis
	Testicular pathology in men (eg, torsion, orchitis)
Mesentery, omentum, and peritoneum	Omental infarct
	Epiploic appendagitis
	Mesenteric adenitis
	Metastatic disease
Musculoskeletal	Abdominal wall haematoma
	Abdominal wall infection
	Muscular sprain/injury
Vascular	Ruptured aneurysm (eg, iliac)
	Gonadal vein thrombosis
	Iliac venous thrombosis

dependent on local availability, and expertise but is pivotal when making a choice of modality.

Ultrasound

US is a widely available imaging modality at most institutions. It is a relatively inexpensive, non-invasive method of investigating RLQ pain, with the added advantage of avoiding ionizing radiation. As an operator-dependent test, variable sensitivities and specificities have been reported for the diagnosis of acute appendicitis (sensitivity of 76%–90% and specificity of 83%–100%).^{9,10} The rate of appendix visualization is also reported to be both sonographer and radiologist-dependent,¹¹ with inconclusive results in 15% to 84% of cases.^{12–14} Knowledge and awareness of local expertise is therefore necessary when considering US in the context of acute RLQ pain and suspected appendicitis. If local technologists and radiologists are less proficient in performing these studies and making the diagnosis, CT may be a more appropriate alternative.

If RLQ US is available and rapidly accessible, it should be considered a first-line modality for patients <30 years old

with a body mass index (BMI) <25. Using a cut-off of 30 years of age minimizes radiation exposure in younger individuals but may increase the number of patients requiring a second test. The Working Group reached a consensus that for the Canadian population, the relatively higher degree of intra-peritoneal fat in most patients over the age of 30 favours the use of CT over US. A BMI less than or equal to 25 is specified to maximize the likelihood of obtaining a conclusive result.¹⁵ If gynaecological pathology is a primary diagnostic consideration in a female patient, US is the test of choice regardless of age/BMI, as it can be tailored to include both RLQ and pelvic assessment, including endovaginal sonography. US may also be considered in patients who have had multiple prior CT studies in order to minimize the cumulative radiation dose.¹⁶

The above scenario (BMI <25, age <30 years old) becomes less relevant when comorbidities are present. For example, if the patient has an oncological history or suspected complications from another known pathology (eg, inflammatory bowel disease), CT would be the preferred first-line modality.

Computed Tomography

In all other non-pregnant patients with undifferentiated RLQ pain or for those with an inconclusive US study, CT is the most appropriate imaging modality. Diagnostic yield with CT is excellent and it provides a survey of all relevant anatomy, assessing for the primary suspected pathology as well as any alternative diagnoses.¹⁷ Intravenous (IV) iodinated contrast is usually recommended unless contraindicated (see next section).^{18,19} The sensitivity and specificity of CT for diagnosing acute appendicitis are high (sensitivity 95% (95% confidence interval [CI]: 0.93–0.96) and specificity 94% (95% CI: 0.92–0.95)).¹⁸ The use of CT has been associated with a significant decrease in the negative appendectomy rate.²⁰

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is generally reserved for pregnant patients and will be addressed last in the guideline. MRI does not offer any significant improvement in sensitivity or specificity for the diagnosis of acute appendicitis over non-contrast CT,²¹ and considering access challenges and exam length, there is little role for MRI in the initial diagnosis of RLQ pain. MRI should generally be reserved as a problem-solving modality, acknowledging that some centres with greater access to the modality may elect to perform MRI in carefully selected young patients after a nondiagnostic US.

Practice Point: If easily accessible with adequate local expertise, US is the first-line imaging modality in female patients where gynecologic pathology is clinically suspected and should be considered as the first-line modality for patients under the age of 30 with a BMI <25. Otherwise, CT should be the first-line imaging test unless the patient is pregnant (Figure 1).

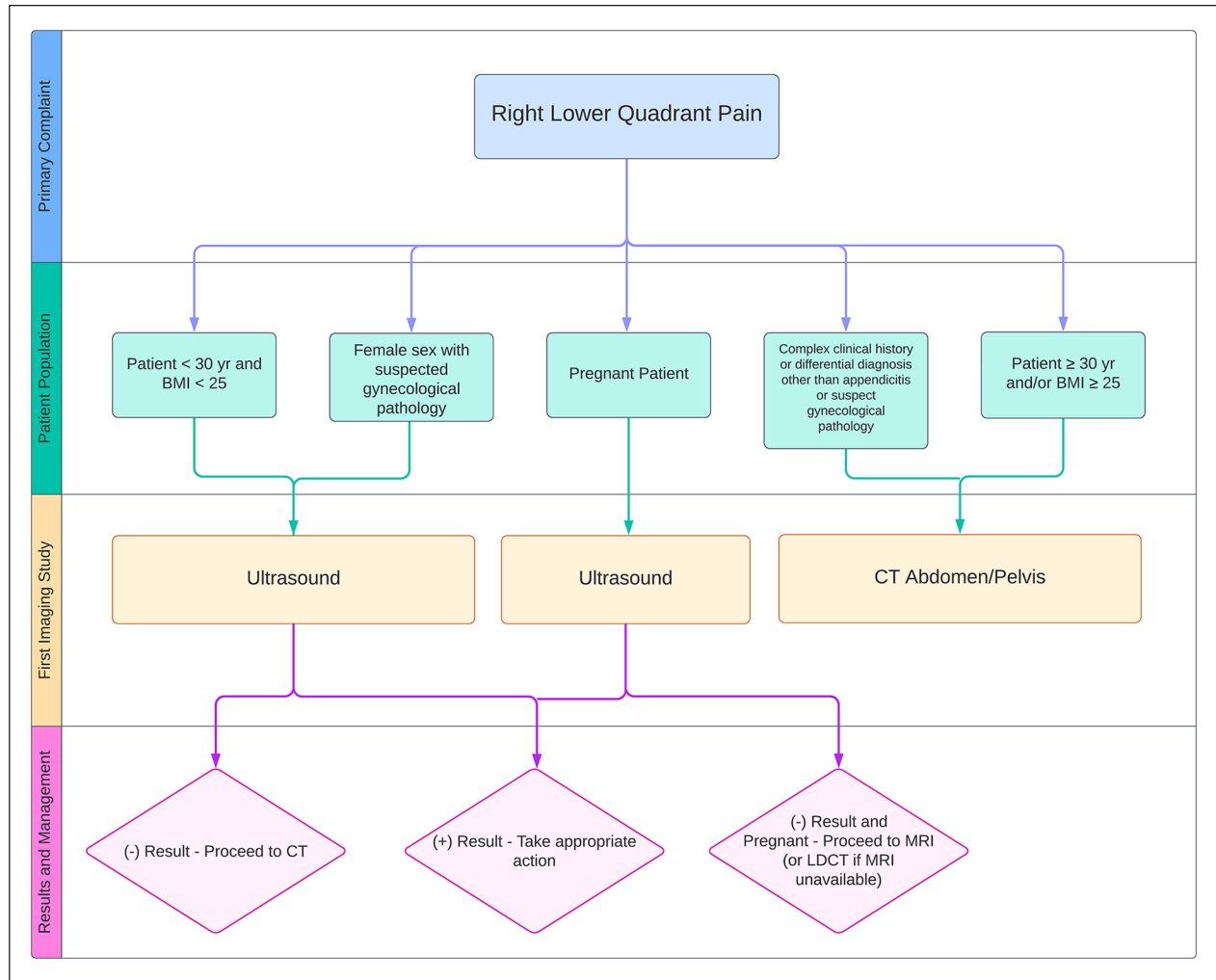


Figure 1. Right lower quadrant pain imaging modality algorithm.

Imaging Protocols

Ultrasound

In EDs, imaging may be used to triage patients prior to assessment by an emergency physician. Although a requisition may indicate a presumptive diagnosis of acute appendicitis, these clinical histories are often recorded before completing a physical examination and obtaining laboratory results. It cannot be assumed that other diagnoses have been adequately excluded. When US is used as a first line modality for assessment of RLQ pain, the expert panel therefore recommends that a comprehensive, rather than targeted, US be performed. This should include evaluation of the following abdominal and pelvic structures: liver, gallbladder, kidneys, pancreas, RLQ/appendix, bladder, ureterovesical junctions, gynaecologic organs in female patients, and hepatorenal recess/pelvis for free fluid assessment.

Pelvic US should be performed with a full bladder to optimize evaluation of the gynaecologic organs. A curved 3 to 5MHz transducer is recommended for global assessment,

followed by targeted assessment using a higher frequency linear transducer (10-12 mHz). Both transabdominal and transvaginal US should be performed in all eligible female patients of reproductive age.

Graded compression US is advised as part of the standard protocol for assessing RLQ pain, with detection of the appendix reported in 60% to 83% of patients.²² The technique simulates deep abdominal palpation by using the transducer and operator's hands to apply pressure, displacing organs during exhalation.

Self-localization by the patient to the area of maximum tenderness can be very useful in the diagnosis of acute appendicitis and is also recommended as part of the focused technique.²³

Practice Points: US for the workup of RLQ pain should be performed as a comprehensive examination evaluating not only the RLQ/appendix, but also the pelvic and remaining solid organs. Endovaginal scanning should be performed in female patients.

Computed Tomography

IV contrast-enhanced CT of the abdomen and pelvis is recommended as the first-line study for the evaluation of RLQ pain in most patients. A systematic review including 64 studies and 10280 patients showed improved sensitivity with IV contrast-enhanced CT imaging (96% [92%-98%]) over noncontrast CT (91% [87%-93%]) for the diagnosis of appendicitis.¹⁸ In cases where there is an absolute contraindication to IV contrast, such as prior severe allergic reaction or high risk of contrast-induced nephropathy, noncontrast CT may be the only option, but the diagnostic performance is still reasonable, with a sensitivity of 86% to 95%, and specificity of 92% to 97.5%.^{24,25}

Routine administration of oral contrast in CT evaluation of RLQ pain is not recommended. A systematic review including 23 studies and 3474 patients comparing CT performance with and without oral contrast showed similar sensitivities (92% vs 95%, respectively) and specificities (94% vs 97%, respectively) between both protocols.²⁶ Many prospective and retrospective studies have also shown that oral contrast does not increase diagnostic performance, and repeat CT with oral contrast was only necessary in 0.2% of cases.²⁷⁻²⁹ Foregoing the administration of oral contrast allows for a more timely diagnosis, avoids unnecessary delays in treatment, and discomfort in patients presenting with RLQ pain.^{27,30}

The routine administration of rectal contrast in CT evaluation of RLQ pain is not indicated. A prospective multicentre study including 56 hospitals and 8089 patients undergoing nonelective appendectomy found similar radiology-pathology concordance rates between IV contrast-enhanced CT and IV contrast-enhanced CT with enteral (oral and/or rectal) contrast.²⁷ Furthermore, rectal contrast administration requires rectal catheterization, which is often an uncomfortable procedure for both patients and CT technologists.³¹

In young patients for whom radiation exposure is of concern, low-dose CT (LDCT) with IV contrast may be performed to evaluate for RLQ pain. Single-centre and multicentre randomized-controlled trials including 891 and 3074 patients aged 15 to 44 years presenting with suspected appendicitis found that contrast-enhanced LDCT (2 mSv) was noninferior to contrast-enhanced standard-dose CT (3-8 mSv) and both modalities had similar negative appendectomy rates and diagnostic performance.^{32,33} However, it is worth noting that less than 5% of the studied patient population had a BMI over 30.^{32,33} Although image degradation due to noise can be of concern when scanning obese patients with a low-dose protocol, increased intra-abdominal fat may conversely help visualize the appendix in these patients.³³ LDCT can be obtained through various methods, such as by decreasing the tube current (mA), increasing the degree of iterative or deep-learning based reconstruction, or altering the noise index of the acquisition. However,

before implementing LDCT in the clinical setting, consultation with local medical physicists and application specialists is recommended to build a low-dose protocol that best suits each institution's CT scanner. It is more important to obtain a confident diagnosis of appendicitis than to obtain a small reduction in ionizing radiation at the expense of CT sensitivity and specificity.

Limited field-of-view (FOV) CT covering only the pelvis is not recommended as first-line imaging for the evaluation of RLQ pain. Retrospective studies evaluating pelvic CT below the iliac crests showed missed alternative diagnoses in 16% to 26% of patients presenting with suspected appendicitis.^{34,35} Sensitivity for limited FOV pelvic CT was found to be significantly lower than that of full-range CT (88% vs 99%, $P < .05$).³⁴ However, a limited FOV CT may be considered in young patients who have already undergone full abdominal-pelvic US imaging to exclude alternative diagnoses. Retrospective studies showed that reducing scan range to cover the superior vertebral endplate of L2 to the superior border of the pubic symphysis is adequate to fully visualize the appendix in patients who had previously undergone inconclusive US for suspected appendicitis.³⁶⁻³⁸ Limiting the scan range from the superior vertebral endplate of L1 to the inferior border of the pubic symphysis can also reduce total effective radiation dose by 39%.³⁶

Shielding of radiosensitive organs during CT examinations is no longer recommended.^{39,40} Proper placement of contact shields is difficult. They can often migrate or become misplaced, which leads to suboptimal dose reduction.^{39,40} Incorrect placement of shields can even lead to increased radiation exposure if obscured anatomy warrants repeat imaging, or when the shields are detected by automatic exposure control systems, which results in unwanted increases in radiation output.^{39,40} Contact shielding is also inefficient against radiation from internal scatter, a substantial source of radiation from CT imaging.^{39,40} Furthermore, other advancements in CT technology have allowed for significant dose reduction while maintaining image quality without the use of shields.³⁹

Multi-energy CT (MECT) is a CT technique that acquires images using photon spectra of different energy levels to allow for the characterization and differentiation of various tissues, including calcium and iodine.⁴¹ The terms multi-energy CT, dual energy CT, and spectral CT are often used interchangeably. In abdominal imaging, MECT can be used to differentiate well-perfused bowel wall from necrotic bowel-wall by identifying iodine in the wall or by making it more visually conspicuous.⁴¹ A retrospective study found that gangrenous appendicitis can be distinguished from uncomplicated appendicitis using beams at 80 to 100 kVp and 140 to 150 kVp.^{41,42} Potential drawbacks of MECT include difficulties in maintaining dose-neutral radiation exposure compared with standard single-energy CT, restrictions in pitch with certain manufacturers, increased number of images, storage requirements, more complex post-processing, and increased

Table 2. Recommended MRI Sequences for Assessment of RLQ Pain in Adult Patients.

Sequences	Protocol recommendation	Details and rationale
Minimum required	<ul style="list-style-type: none"> Initial acquisition: Thick section (5-8 mm) axial and coronal T2 SSFSE or HASTE Thinner section (3-5 mm) T2 SSFSE/HASTE images in multiple planes Frequency-selective fat saturated T2-weighted sequence in one plane 	<ul style="list-style-type: none"> Coverage: abdomen and pelvis or pelvis only, depending on patient presentation To localize area of pain, locate position of the appendix Radiologist should review initial images before planning thin section sequences For detailed assessment Detection of inflammatory changes and/or oedema
Recommended, but not required	<ul style="list-style-type: none"> DWI/ADC with highest b-value ≥ 800 	<ul style="list-style-type: none"> Increased conspicuity of inflammation/oedema
Optional	<ul style="list-style-type: none"> Gadolinium-enhanced, multiphase T1-weighted 3D spoiled-gradient echo with fat saturation 	<ul style="list-style-type: none"> Assess appendix wall and periappendiceal soft tissues Avoid gadolinium in pregnancy (category C drug)

interpretation times.⁴³ Therefore, in institutions that have not already adopted MECT as the standard emergency abdominal CT acquisition technique for other reasons, MECT is not specifically recommended for the evaluation of RLQ pain.

Practice Points: CT for RLQ pain should be performed with iodinated IV contrast. Oral and rectal contrast is not recommended. Low-dose and limited FOV CT can be used judiciously when minimizing radiation exposure is a particular concern (limited FOV CT only after a full US). Shielding is not recommended.

Magnetic Resonance Imaging

Recognizing the challenge of appendix non-visualization, a combined approach using different imaging modalities may be necessary for a confident diagnosis in some patients, predominantly pregnant patients. Vasileiou et al⁴⁴ found that in pregnancy, a combination of abdominal US and MRI was most commonly performed (41%), followed by MRI alone (29%), US alone (22%), CT (5%), and no imaging (2%).

When MRI is performed for RLQ pain, the expert panel recommends use of a phased-array body coil due to its superior signal-to-noise ratio (SNR) relative to the built-in body coil. Antiperistaltic medication such as hyoscine (20 mg IM or IV) has been used in eligible patients to reduce artifacts arising from bowel peristalsis. As there is limited data on the use of hyoscine and other antiperistaltic agents during pregnancy and lactation, it is preferable to avoid its use as a precautionary measure. A 1.5T field strength is preferred, as lower field strengths are less susceptible to artifacts from enteric gas, motion, and peristalsis compared to 3T.

The expert panel MRI protocol recommendations are listed in Table 2.

The use of abbreviated MRI protocols is becoming more common in abdominal imaging to reduce imaging and interpretation time. In a prospective study of 67 patients with clinical suspicion of acute appendicitis, Islam et al⁴⁵ used an

abbreviated protocol consisting of axial and coronal T2WI SSFSE/HASTE (3 mm slice thickness) and axial DWI, and found a sensitivity of 93.3%, specificity of 86.4%, and diagnostic accuracy of 91.0%. Mian et al⁴⁶ also found that abbreviated protocols consisting of HASTE and DWI images reduce imaging and interpretation times in the diagnosis of acute appendicitis, with similar accuracy to a full protocol.

Practice Points: Multiplanar single-shot fast spin echo T2-weighted sequences should form the basis of any MRI protocol for acute appendicitis.

Right Lower Quadrant Pain in Pregnancy

Clinical Context

The overall prevalence of appendicitis during pregnancy is 0.001% to 0.004%.⁴⁷ Widespread use of imaging has reduced the rate of negative laparotomy to 1% to 3% versus 25% to 30% historically.¹⁹ Unfortunately, more than 15% to 30% of patients who undergo an appendectomy, specifically in the second and third trimester, still have a normal appendix.^{48,49} This is not inconsequential, as laparotomy increases the risk of pre-term delivery and is associated with surgical complications. Conversely, the risk of appendiceal perforation is increased to 66% in the setting of a delayed diagnosis which can result in an increased risk of fetal loss and maternal mortality if left untreated for >24 hours.⁵⁰ The rate of fetal loss increases from 2% when appendicitis is unruptured to >30% when the appendix has ruptured.⁵¹⁻⁵³

Imaging Issues Specific to Pregnancy

There is an anatomical alteration in the location of the appendix during pregnancy arising from anterior and superior peritoneal displacement. Presenting symptoms may be vague and non-specific. When coupled with a limited physical examination

and an atypical location of pain, the diagnosis may be delayed or confounded. Moreover, physiological elevation of the white blood cell count and C-reactive protein during pregnancy can further lead to misinterpretation.⁵⁴ US can be sensitive when performed by experienced sonographers, but is operator dependent (sensitivity 56% and a specificity of 88%).⁵⁵ As the appendix displaces cranially during the third trimester and bowel loops are compressed against each other, locating the appendix becomes increasingly difficult as the pregnancy progresses. US remains the first line test as it has reasonable performance characteristics, is free of ionizing radiation and can offer alternate diagnoses in the setting of acute pain. Several studies have shown that MRI in pregnancy has a sensitivity and specificity for detecting appendicitis of up to 100% and 94% to 100%, respectively.^{53,56-58} A systematic review and meta-analysis of 19 studies reinforced these findings by demonstrating a sensitivity and specificity of 91.8% and 97.9%, respectively.⁵⁹ This accuracy was also replicated by readers with variable experience who achieved an accuracy of 99.8% and positive predictive value of 100% for the presence of acute appendicitis.⁶⁰

Consent

Guidelines vary with regards to consent and may vary between jurisdiction and regulatory bodies. The Working Group agrees with the ACR that consent may be either verbal or written but should be documented. The latter should be uploaded either as an attachment to PACS or within the electronic patient medical record. An example of wording that could be used in a consent form is given in Appendix A.

Practice Points: Either verbal or written consent for MRI should be documented in the medical record.

Technique

The MRI technique in pregnancy has been previously described, but several key points should be reinforced. In the pregnant population, the use of gadolinium is not recommended unless absolutely necessary for acquiring information that cannot be otherwise obtained and if its use would meaningfully alter management (which is typically unlikely). Although there are no documented adverse outcomes associated with MRI in any trimester of pregnancy at 1.5 or 3T, most recommend using 1.5T in the first trimester if both field strengths are available. Given this, and owing to increased susceptibility artifacts at 3T, the Working Group recommends that all pregnant patients be scanned at 1.5T if possible. There is insufficient evidence at this point to recommend scanning at a field strength of <1.5T. Specific absorption rate (SAR) and energy deposition are a theoretical concern, but sequence parameters and radiofrequency pulse design will automatically adjust to lower SAR on modern scanners.⁶¹ DWI can increase the sensitivity of MRI in the detection of the appendix and specifically has increased

potential to improve performance in the novice or less subspecialty trained reader, at the expense of increased SAR.^{60,62}

Practice Points: MRI in pregnancy should be performed on a 1.5T scanner without gadolinium.

Which Modality and in Which Order?

Data on the modality and ideal order of investigations remains anecdotal, but outside the confines of academic institutions and larger communities, the availability of MRI to image pregnant patients urgently is limited in Canada. US is widely used as the first line of imaging in pregnant patients with an acute abdomen as it is inexpensive, portable, free of ionizing radiation, reasonably sensitive, and specific in experienced hands.⁶³ As previously stated, the sensitivity of US is adversely affected by bowel gas, body habitus, pain, and displacement of normal anatomy by the gravid uterus—all of which become more problematic as a pregnancy advances. Higher rates of inconclusive results (up to 63%-97%) have been reported after 24 weeks of gestation^{64,65} compared to the first trimester (26%).⁶⁴ This finding has led some institutions to advocate for noncontrast MRI of the abdomen as an initial modality of investigation in pregnant patients with suspected acute appendicitis.⁶⁶ This approach remains limited to centres with streamlined access to MRI and radiologist expertise to interpret the studies. However, the current reality in Canada is that few centres can provide this option. Despite demonstrating mediocre accuracy in later trimesters, it is the opinion of the Working Group that US should always be performed prior to MRI given the ease of access and relative complexity of arranging MRI in most emergent settings.^{63,67} In most Canadian institutions, even if an MRI is requested, an US could be performed in the time it takes for the scan to be arranged.

Given the ionizing radiation involved with CT, this should be an option of last resort except in cases of a trauma-related RLQ pain in pregnant patients,^{63,68,69} as supported by the European Society of Urogenital Radiology (ESUR) and ACR. There is a role for low-dose CT if MRI is unavailable or inaccessible (also supported in this setting by ESUR recommendations), but there is no consensus on the specific LDCT protocol. Low-dose CT is non-inferior to conventional dose CT in the imaging of both gravid and non-gravid patients.^{32,68} In one study, low-dose CT was able to confirm or rule out the diagnosis of appendicitis, or provide an alternate explanation for RLQ pain in 83% of the patients scanned.⁶⁸ That said, the Working Group feels it is more important to establish a definitive diagnosis than obtain a technically suboptimal scan which could be both non-diagnostic and delay care for further downstream testing. We recommend that departments work collaboratively with their medical physicist and CT vendors (and respective application specialists) to use as much iterative or deep-learning reconstruction as possible to minimize dose while maintaining study quality. If a CT is performed, iodinated IV contrast should be considered (unlike

gadolinium-based contrast agents, iodinated contrast agents are not contraindicated in pregnancy).

Practice Points: All pregnant patients with RLQ pain requiring imaging should undergo US first (Figure 1). MRI is recommended as the next modality of choice for problem-solving. CT should be reserved for when MRI is unavailable or in trauma-related RLQ pain, and IV contrast is recommended in most cases. While low-dose CT acquisition is desirable, the main goal is to establish a definitive diagnosis and the accuracy of the test should not be compromised by an excessively low dose if the providing centre is not experienced with such techniques.

The Role of Specialist Consultation: When and Whom?

There is no clear consensus on when to include a specialist consultation in the management of pregnant patients presenting with RLQ pain. The European Association for Endoscopic Surgery rapid guideline recommends operative treatment over conservative management in pregnant patients with complicated appendicitis or appendicoliths on imaging studies (strong recommendation) and suggests operative treatment over conservative management in pregnant patients with uncomplicated appendicitis and no appendicolith on imaging studies (weak recommendation).⁷⁰ Extrapolating from these guidelines and based on consensus opinion, we suggest early involvement of a surgical consultant in the pregnant patient presenting with RLQ pain. The specific surgical specialty needed can be guided by first- or second-line imaging findings and early emergency medical workup. Consultation could be obtained as early as after first-line US evaluation, even if equivocal, and either MRI (preferred) or CT (last resort) are required to navigate decision-making with the management plan in mind well in advance. This can also assist in the best approach to patient counselling and guidance in informed decision-making.

Practice Points: Surgical consultation is recommended prior to MRI or CT evaluation of pregnant patients with RLQ pain.

Conclusion

The evaluation of patients with RLQ pain should be geared towards timely diagnosis with minimal testing to reduce patient morbidity and healthcare costs. The Working Group has provided a framework to aid in this process for various clinical scenarios and has addressed current questions and controversies, particularly those relevant to the Canadian healthcare system.

Appendix A

Sample Consent Form for MRI in Pregnancy

Your doctor has referred you for an MRI examination during your pregnancy.

To date, there is no evidence that the use of MRI on patients in pregnancy causes any harm to the mother or fetus, but MRI has not been declared absolutely safe in pregnancy by Health Canada or the U.S. Food and Drug Administration due to the lack of long-term, large-scale data. The American College of Obstetrics and Gynecology has issued a statement recommending that MRI be performed in pregnancy when it may provide medical benefit and that it should not be considered associated with risk.

The MRI scanner can be quite loud, but your body will protect the fetus from the sound and there is no evidence that it will affect the hearing of your unborn child. The MRI scanner uses magnetic fields and radio waves to take pictures and does not use X-rays. The radio wave energy used in MRI can potentially warm up tissues in the body, so we will limit the amount of energy you receive and monitor this energy to ensure it remains at low levels. We will not be using intravenous contrast for this MRI.

Consent to Proceed With Examination

My doctor is aware of my pregnancy, and I have read the above information and agree to proceed with my MRI examination.

Signature of Patient and Date

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Declaration of Conflicting Interests


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References

- Expert Panel on Gastrointestinal Imaging, Kambadakone AR, Santillan CS, et al. ACR Appropriateness Criteria® right lower quadrant pain: 2022 update. *J Am Coll Radiol*. 2022;19(11S):S445-S461. doi:10.1016/j.jacr.2022.09.011
- Desoky SM, George M, Epelman M, et al. Imaging of right lower quadrant pain in children and adolescents: AJR expert panel narrative review. *AJR Am J Roentgenol*. 2023;220(6):767-779. doi:10.2214/AJR.22.28358
- Hastings RS, Powers RD. Abdominal pain in the ED: a 35 year retrospective. *Am J Emerg Med*. 2011;29(7):711-716. doi:10.1016/j.ajem.2010.01.045
- Morley EJ, Bracey A, Reiter M, Thode HC, Singer AJ. Association of pain location with computed tomography abnormalities in emergency department patients with abdominal pain. *J Emerg Med*. 2020;59(4):485-490. doi:10.1016/j.jemermed.2020.06.002
- Patel NB, Wenzke DR. Evaluating the patient with right lower quadrant pain. *Radiol Clin North Am*. 2015;53(6):1159-1170. doi:10.1016/j.rcl.2015.06.004
- Heller MT, Hattoum A. Imaging of acute right lower quadrant abdominal pain: differential diagnoses beyond appendicitis. *Emerg Radiol*. 2012;19(1):61-73. doi:10.1007/s10140-011-0997-9
- Sharma P, Hegde R, Kulkarni A, Soim P, Kochar P, Rotem E. Imaging right lower quadrant pain: not always appendicitis. *Clin Imaging*. 2020;63:65-82. doi:10.1016/j.clinimag.2020.02.012
- Rosenkrantz AB, Labib A, Ginocchio LA, Babb JS. Evaluation for suspected acute appendicitis in the emergency department setting: a comparison of outcomes among three imaging pathways. *Clin Imaging*. 2016;40(4):788-792. doi:10.1016/j.clinimag.2016.02.022
- Keyzer C, Zalzman M, De Maertelaer V, et al. Comparison of US and unenhanced multi-detector row CT in patients suspected of having acute appendicitis. *Radiology*. 2005;236(2):527-534. doi:10.1148/radiol.2362040984
- Parks NA, Schroepel TJ. Update on imaging for acute appendicitis. *Surg Clin North Am*. 2011;91(1):141-154. doi:10.1016/j.suc.2010.10.017
- Gilligan LA, Trout AT, Davenport MS, Zhang B, O'Hara SM, Dillman JR. Variation in imaging outcomes associated with individual sonographers and radiologists in pediatric acute appendicitis: a retrospective cohort of 9271 examinations. *Eur Radiol*. 2021;31(11):8565-8577. doi:10.1007/s00330-021-07939-1
- Fedko M, Bellamkonda VR, Bellolio MF, et al. Ultrasound evaluation of appendicitis: importance of the 3 × 2 table for outcome reporting. *Am J Emerg Med*. 2014;32(4):346-348. doi:10.1016/j.ajem.2013.12.052
- Poortman P, Oostvogel HJM, Bosma E, et al. Improving diagnosis of acute appendicitis: results of a diagnostic pathway with standard use of ultrasonography followed by selective use of CT. *J Am Coll Surg*. 2009;208(3):434-441. doi:10.1016/j.jamcollsurg.2008.12.003
- Crocker C, Akl M, Abdolell M, Kamali M, Costa AF. Ultrasound and CT in the diagnosis of appendicitis: accuracy with consideration of indeterminate examinations according to STARD guidelines. *AJR Am J Roentgenol*. 2020;215(3):639-644. doi:10.2214/AJR.19.22370
- Josephson T, Styruud J, Eriksson S. Ultrasonography in acute appendicitis. Body mass index as selection factor for US examination. *Acta Radiol*. 2000;41(5):486-488. doi:10.1080/028418500127345749
- Kavanagh RG, O'Grady J, Carey BW, et al. Low-dose computed tomography for the optimization of radiation dose exposure in patients with Crohn's disease. *Gastroenterol Res Pract*. 2018;2018:1768716. doi:10.1155/2018/1768716
- Pooler BD, Lawrence EM, Pickhardt PJ. Alternative diagnoses to suspected appendicitis at CT. *Radiology*. 2012;265(3):733-742. doi:10.1148/radiol.12120614
- Rud B, Vejborg TS, Rappeport ED, Reitsma JB, Wille-Jørgensen P. Computed tomography for diagnosis of acute appendicitis in adults. *Cochrane Database Syst Rev*. 2019;2019(11):CD009977. doi:10.1002/14651858.CD009977.pub2
- Expert Panel on Gastrointestinal Imaging; Garcia EM, Camacho MA, et al. ACR Appropriateness Criteria® right lower quadrant pain-suspected appendicitis. *J Am Coll Radiol JACR*. 2018;15(11S):S373-S387. doi:10.1016/j.jacr.2018.09.033
- Kontopodis N, Kouraki A, Panagiotakis G, Chatziioannou M, Spiridakis K. Efficacy of preoperative computed tomography imaging to reduce negative appendectomies in patients undergoing surgery for left lower quadrant abdominal pain. *G Chir*. 2014;35(9-10):223-228.
- Kinner S, Pickhardt PJ, Riedesel EL, et al. Diagnostic accuracy of MRI versus CT for the evaluation of acute appendicitis in children and young adults. *AJR Am J Roentgenol*. 2017;209(4):911-919. doi:10.2214/AJR.16.17413
- Lee JH, Jeong YK, Park KB, Park JK, Jeong AK, Hwang JC. Operator-dependent techniques for graded compression sonography to detect the appendix and diagnose acute appendicitis. *AJR Am J Roentgenol*. 2005;184(1):91-97. doi:10.2214/ajr.184.1.01840091
- Chesbrough RM, Burkhard TK, Balsara ZN, Goff WB, Davis DJ. Self-localization in US of appendicitis: an addition to graded compression. *Radiology*. 1993;187(2):349-351. doi:10.1148/radiology.187.2.8475271
- Xiong B, Zhong B, Li Z, et al. Diagnostic accuracy of noncontrast CT in detecting acute appendicitis: a meta-analysis of prospective studies. *Am Surg*. 2015;81(6):626-629.
- Hlibczuk V, Dattaro JA, Jin Z, Falzon L, Brown MD. Diagnostic accuracy of noncontrast computed tomography for appendicitis in adults: a systematic review. *Ann Emerg Med*. 2010;55(1):51-59.e1. doi:10.1016/j.annemergmed.2009.06.509
- Anderson BA, Salem L, Flum DR. A systematic review of whether oral contrast is necessary for the computed tomography diagnosis of appendicitis in adults. *Am J Surg*. 2005;190(3):474-478. doi:10.1016/j.amjsurg.2005.03.037
- Drake FT, Alfonso R, Bhargava P, et al. Enteral contrast in the computed tomography diagnosis of appendicitis. *Ann Surg*. 2014;260(2):311-316. doi:10.1097/SLA.0000000000000272
- Glauser J, Siff J, Emerman C. Emergency department experience with nonoral contrast computed tomography in the evaluation

- of patients for appendicitis. *J Patient Saf.* 2014;10(3):154-158. doi:10.1097/PTS.0b013e31829a07ba
29. Uyeda JW, Yu H, Ramalingam V, Devalapalli AP, Soto JA, Anderson SW. Evaluation of acute abdominal pain in the emergency setting using computed tomography without oral contrast in patients with body mass index greater than 25. *J Comput Assist Tomogr.* 2015;39(5):681-686. doi:10.1097/RCT.0000000000000277
 30. Schuur JD, Chu G, Sucov A. Effect of oral contrast for abdominal computed tomography on emergency department length of stay. *Emerg Radiol.* 2010;17(4):267-273. doi:10.1007/s10140-009-0847-1
 31. Madsen AH, Al-Ubadi SJ, Christensen DB, Christensen JB, Madsen MR. Rectal enhanced CT-scans and acute appendicitis: a modality to exclude appendicitis? *Glob Surg.* 2017;3(1):1-3. doi:10.15761/GOS.1000147
 32. Kim K, Kim YH, Kim SY, et al. Low-dose abdominal CT for evaluating suspected appendicitis. *N Engl J Med.* 2012;366(17):1596-1605. doi:10.1056/NEJMoa1110734
 33. LOCAT Group. Low-dose CT for the diagnosis of appendicitis in adolescents and young adults (LOCAT): a pragmatic, multicentre, randomised controlled non-inferiority trial. *Lancet Gastroenterol Hepatol.* 2017;2(11):793-804. doi:10.1016/S2468-1253(17)30247-9
 34. Kamel IR, Goldberg SN, Keogan MT, Rosen MP, Raptopoulos V. Right lower quadrant pain and suspected appendicitis: nonfocused appendiceal CT—review of 100 cases. *Radiology.* 2000;217(1):159-163. doi:10.1148/radiology.217.1.r00oc34159
 35. Brassart N, Winant C, Tack D, Gevenois PA, De Maertelaer V, Keyzer C. Optimised z-axis coverage at multidetector-row CT in adults suspected of acute appendicitis. *Br J Radiol.* 2013;86(1028):20130115. doi:10.1259/bjr.20130115
 36. Zinsser D, Maurer M, Do PL, et al. Reduced scan range abdominopelvic CT in patients with suspected acute appendicitis - impact on diagnostic accuracy and effective radiation dose. *BMC Med Imaging.* 2019;19:4. doi:10.1186/s12880-019-0304-x
 37. O'Malley ME, Alharbi F, Chawla TP, Moshonov H. CT following US for possible appendicitis: anatomic coverage. *Eur Radiol.* 2016;26(2):532-538. doi:10.1007/s00330-015-3778-0
 38. Dowhanik A, Tonkopi E, Crocker CE, Costa AF. Diagnostic performance and radiation dose of reduced vs. standard scan range abdominopelvic CT for evaluation of appendicitis. *Eur Radiol.* 2021;31(10):7817-7826. doi:10.1007/s00330-021-07945-3
 39. Hiles P, Gilligan P, Damilakis J, et al. European consensus on patient contact shielding. *Insights Imaging.* 2021;12(1):194. doi:10.1186/s13244-021-01085-4
 40. Marsh RM, Silosky M. Patient shielding in diagnostic imaging: discontinuing a legacy practice. *AJR Am J Roentgenol.* 2019;212(4):755-757. doi:10.2214/AJR.18.20508
 41. Elbanna KY, Mohammed MF, Chahal T, et al. Dual-energy CT in differentiating nonperforated gangrenous appendicitis from uncomplicated appendicitis. *AJR Am J Roentgenol.* 2018; 211(4):776-782. doi:10.2214/AJR.17.19274
 42. Topel Ç, Onur MR, Akpınar E, Karaosmanoğlu AD, Akata D, Karçaaltınçaba M. Low tube voltage increases the diagnostic performance of dual-energy computed tomography in patients with acute appendicitis. *Diagn Interv Radiol.* 2019;25(4):257-264. doi:10.5152/dir.2019.18567
 43. Borges AP, Antunes C, Curvo-Semedo L. Pros and cons of dual-energy CT systems: “one does not fit all.” *Tomography.* 2023;9(1):195-216. doi:10.3390/tomography9010017
 44. Vasileiou G, Eid AI, Qian S, et al. Appendicitis in pregnancy: a post-hoc analysis of an EAST multicenter study. *Surg Infect (Larchmt).* 2020;21(3):205-211. doi:10.1089/sur.2019.102
 45. Islam GMN, Yadav T, Khera PS, et al. Abbreviated MRI in patients with suspected acute appendicitis in emergency: a prospective study. *Abdom Radiol (NY).* 2021;46(11):5114-5124. doi:10.1007/s00261-021-03222-5
 46. Mian M, Khosa F, Ali IT, et al. Faster magnetic resonance imaging in emergency room patients with right lower quadrant pain and suspected acute appendicitis. *Pol J Radiol.* 2018;83:e340-e347. doi:10.5114/pjr.2018.77790
 47. Andersen B, Nielsen TF. Appendicitis in pregnancy: diagnosis, management and complications. *Acta Obstet Gynecol Scand.* 1999;78(9):758-762.
 48. Pedrosa I, Lafornera M, Pandharipande PV, Goldsmith JD, Rofsky NM. Pregnant patients suspected of having acute appendicitis: effect of MR imaging on negative laparotomy rate and appendiceal perforation rate. *Radiology.* 2009;250(3):749-757. doi:10.1148/radiol.2503081078
 49. McGory ML, Zingmond DS, Tillou A, Hiatt JR, Ko CY, Cryer HM. Negative appendectomy in pregnant women is associated with a substantial risk of fetal loss. *J Am Coll Surg.* 2007;205(4):534-540. doi:10.1016/j.jamcollsurg.2007.05.025
 50. Tamir IL, Bongard FS, Klein SR. Acute appendicitis in the pregnant patient. *Am J Surg.* 1990;160(6):571-575; discussion 575-576. doi:10.1016/s0002-9610(05)80748-2
 51. Abbasi N, Patenaude V, Abenhaim HA. Evaluation of obstetrical and fetal outcomes in pregnancies complicated by acute appendicitis. *Arch Gynecol Obstet.* 2014;290(4):661-667. doi:10.1007/s00404-014-3276-7
 52. Silvestri MT, Pettker CM, Brousseau EC, Dick MA, Ciarleglio MM, Erekson EA. Morbidity of appendectomy and cholecystectomy in pregnant and nonpregnant women. *Obstet Gynecol.* 2011;118(6):1261-1270. doi:10.1097/AOG.0b013e318234d7bc
 53. Dewhurst C, Beddy P, Pedrosa I. MRI evaluation of acute appendicitis in pregnancy. *J Magn Reson Imaging JMRI.* 2013;37(3):566-575. doi:10.1002/jmri.23765
 54. Burke LMB, Bashir MR, Miller FH, et al. Magnetic resonance imaging of acute appendicitis in pregnancy: a 5-year multiinstitutional study. *Am J Obstet Gynecol.* 2015;213(5):693.e1-693.e6. doi:10.1016/j.ajog.2015.07.026
 55. Wang Z, Bao F, Liang W, et al. Appendicitis in pregnant women: a systematic review and meta-analysis of the diagnostic performance of ultrasonography. *J Clin Ultrasound.* 2023;51(9):1492-1501. doi:10.1002/jcu.23566
 56. Fonseca AL, Schuster KM, Kaplan LJ, Maung AA, Lui FY, Davis KA. The use of magnetic resonance imaging in the diagnosis of suspected appendicitis in pregnancy: shortened length of stay without increase in hospital charges. *JAMA Surg.* 2014;149(7):687-693. doi:10.1001/jamasurg.2013.4658
 57. Zingone F, Sultan AA, Humes DJ, West J. Risk of acute appendicitis in and around pregnancy: a population-based cohort study from England. *Ann Surg.* 2015;261(2):332-337. doi:10.1097/SLA.0000000000000780
 58. Pastore PA, Loomis DM, Sauret J. Appendicitis in pregnancy. *J Am Board Fam Med.* 2006;19(6):621-626. doi:10.3122/jabfm.19.6.621

59. Kave M, Parooie F, Salarzaei M. Pregnancy and appendicitis: a systematic review and meta-analysis on the clinical use of MRI in diagnosis of appendicitis in pregnant women. *World J Emerg Surg.* 2019;14:37. doi:10.1186/s13017-019-0254-1
60. Buckley B, Delaney F, Welaratne I, Windrim C, Geoghegan T, Cronin C. MRI remains highly accurate in the diagnosis of appendicitis in pregnancy when read by radiologists of mixed specialty training and experience. *Emerg Radiol.* 2023;30(1):85-91. doi:10.1007/s10140-022-02102-9
61. Jabehdar Maralani P, Kapadia A, Liu G, et al. Canadian Association of Radiologists recommendations for the safe use of MRI during pregnancy. *Can Assoc Radiol J.* 2022;73(1):56-67. doi:10.1177/084653712111015657
62. Kulali F. Diffusion-weighted imaging versus non-contrast magnetic resonance imaging in the diagnosis of acute appendicitis during pregnancy. *Rev Assoc Medica Bras (1992).* 2023;69(1):56-60. doi:10.1590/1806-9282.20220578
63. Lie G, Eleti S, Chan D, Roshen M, Cross S, Qureshi M. Imaging the acute abdomen in pregnancy: a radiological decision-making tool and the role of MRI. *Clin Radiol.* 2022;77(9):639-649. doi:10.1016/j.crad.2022.05.021
64. Hirsch L, Yogev Y, Ashwal E, From A, Ben-Haroush A, Peled Y. The impact of pregnancy on the accuracy and delay in diagnosis of acute appendicitis. *J Matern Fetal Neonatal Med.* 2014;27(13):1357-1360. doi:10.3109/14767058.2013.858321
65. Lehnert BE, Gross JA, Linnau KF, Moshiri M. Utility of ultrasound for evaluating the appendix during the second and third trimester of pregnancy. *Emerg Radiol.* 2012;19(4):293-299. doi:10.1007/s10140-012-1029-0
66. Ramalingam V, LeBedis C, Kelly JR, Uyeda J, Soto JA, Anderson SW. Evaluation of a sequential multi-modality imaging algorithm for the diagnosis of acute appendicitis in the pregnant female. *Emerg Radiol.* 2015;22(2):125-132. doi:10.1007/s10140-014-1260-y
67. Baruch Y, Canetti M, Blecher Y, Yogev Y, Grisaru D, Michaan N. The diagnostic accuracy of ultrasound in the diagnosis of acute appendicitis in pregnancy. *J Matern Fetal Neonatal Med.* 2020;33(23):3929-3934. doi:10.1080/14767058.2019.1592154
68. Poletti PA, Botsikas D, Becker M, et al. Suspicion of appendicitis in pregnant women: emergency evaluation by sonography and low-dose CT with oral contrast. *Eur Radiol.* 2019;29(1):345-352. doi:10.1007/s00330-018-5573-1
69. Qamar SR, Green CR, Ghandehari H, et al. CETARS/CAR practice guideline on imaging the pregnant trauma patient. *Can Assoc Radiol J.* Published online May 30, 2024. doi:10.1177/08465371241254966
70. Adamina M, Andreou A, Arezzo A, et al. EAES rapid guideline: systematic review, meta-analysis, GRADE assessment, and evidence-informed European recommendations on appendicitis in pregnancy. *Surg Endosc.* 2022;36(12):8699-8712. doi:10.1007/s00464-022-09625-9