Point-of-care ultrasound in the assessment of appendicitis

CASE PRESENTATION

A 15-year-old boy presents to the ED with 1 day of periumbilical non-radiating abdominal pain. The pain, described as a stinging sensation, started gradually 1 day prior to presentation after eating lunch and increased to an intensity of 8 out of 10 at its worst over the day. The patient reports that the pain has since improved to 4 out of 10. He does not have fevers, chills, anorexia, nausea, emesis, urinary symptoms, stool changes, testicular pain or swelling, and prior abdominal surgery. The patient has no significant medical or surgical history, takes no medications and has no allergies.

He is afebrile with other triage vital signs notable for a BP of 135/77 mm Hg, low-grade tachycardia with an HR of 101 beats/min, a normal RR of 18 breaths/min and a normal oxygen saturation of 100% on room air. On physical examination, he is a well-appearing adolescent boy lying in bed in no acute distress. He is breathing comfortably, and his cardiovascular examination reveals strong radial pulses with a regular rate and rhythm, and warm extremities. He has normal bowel sounds. On palpation, his abdomen is soft and flat, but he has tenderness at McBurney's point. There is voluntary guarding, but no rigidity or rebound tenderness. Deep palpation in the left lower quadrant reproduces his pain in the right lower quadrant (RLQ) (Rovsing's sign). On further evaluation, he has no inguinal hernia, and his testicles are neither swollen nor tender. He has no costovertebral angle tenderness. His skin is warm and dry.

A complete blood count reveals no leucocytosis, and a comprehensive metabolic panel including liver function tests is without abnormalities. Inflammatory markers are not obtained. His urine has no occult blood, leucocyte esterase or nitrites.

WHAT ARE THE INDICATIONS FOR EVALUATION OF THE APPENDIX WITH POINT-OF-CARE ULTRASOUND (POCUS)?

History and physical examination alone are often insufficient to rule in or rule out paediatric appendicitis, so imaging including POCUS is often necessary.[1] POCUS of the appendix should be considered when there is undifferentiated abdominal pain and especially if there is clinical suspicion for appendicitis, such as the presence of RLQ or periumbilical abdominal pain, nausea and vomiting, or fever, with abdominal tenderness to palpation. Both the American College of Radiology Appropriateness Criteria and the American College of Emergency Physicians clinical policy statement recommend an ultrasound (US) of the RLQ as the initial study of choice in suspected paediatric appendicitis.[2 3] Although these policies refer to a radiology-performed US, POCUS in the hands of a provider comfortable with proper technique has been shown to be fast and accurate when compared with a radiology-performed study, and has the potential to shorten ED length of stay.[4 5] Therefore, POCUS is worth considering as the initial imaging modality in any paediatric patient with the appropriate characteristics in whom appendicitis is suspected.

WHICH TRANSDUCER IS BEST SUITED FOR PERFORMING POCUS OF THE APPENDIX?

To maximise resolution, the highest possible frequency should be used to visualise the appendix. In most patients, a high-frequency linear transducer (mean frequency 5 MHz or greater) can often penetrate deep enough to visualise the appendix, whereas in larger patients, a deeper-penetrating low-frequency curvilinear transducer (mean frequency between 4 MHz and 6 MHz) may be necessary.[6]

Figure 1 Point-of-care ultrasound of the right lower quadrant using a high-frequency linear transducer reveals a tubular, blind-ended, fluid-filled structure in the longitudinal plane.

WHAT VIEWS SHOULD BE OBTAINED WHEN ASSESSING THE APPENDIX?

There are four views necessary to accurately diagnose appendicitis and to minimise false positives: (1) a view of the tip of the appendix in the long orientation to identify it as a blind-ended tube; (2) a view of the appendix in a transverse orientation to identify it as a circular structure in cross section measuring at least 6 mm in diameter as measured from the most superficial to the deepest wall; (3) an online supplemental video 2 of the appendix, ideally in the transverse orientation, with compression to demonstrate that it is non-compressible and not peristalsing; and (4) online supplemental video 1 tracing the appendix in its entirety from its base, where it joins the cecum to its to tip in either transverse or long in order to provide the full context to adequately convince a viewer that the structure is the appendix.

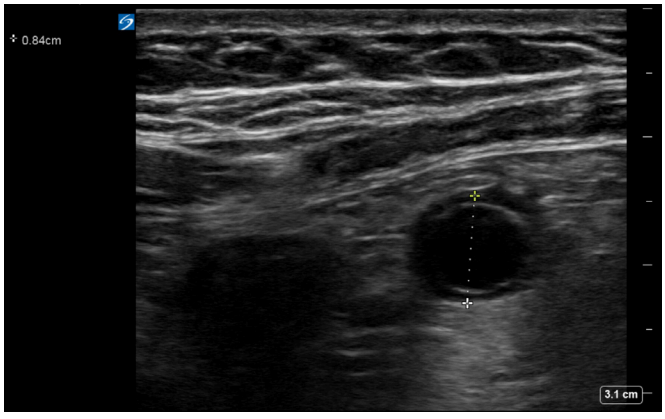

Figure 2 The appendix in the transverse plane measuring 8.4 mm in diameter (measurement in top left corner). Multiple layers of the oedematous bowel wall are visible as alternating hyperechoic and anechoic rings.

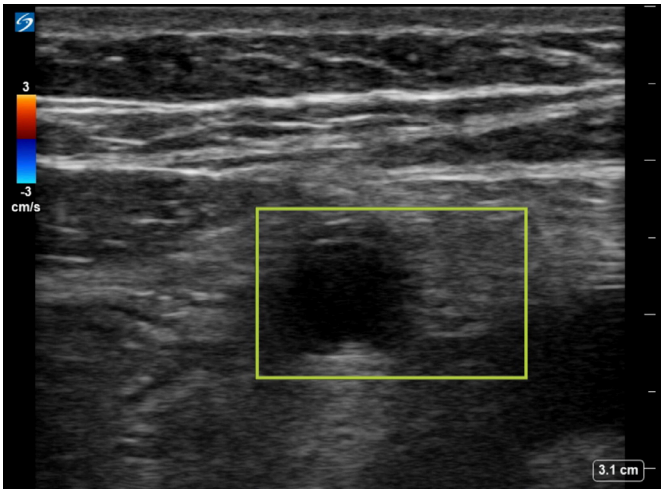

Figure 3 The structure has no pulsatile flow on colour Doppler mode.

An additional helpful view is in the transverse plane with colour Doppler applied to demonstrate that the identified structure is not a vessel and to assess for wall hyperaemia. Assessing for hyperaemia, we found that a pattern of exaggerated colour Doppler flow in the appendiceal wall indicative of increased blood flow is not mandatory but can provide further evidence of inflammation. In order to assess for hyperaemia, the operator must use colour Doppler or power Doppler at a setting to detect low-flow velocities (eg, scale up to 10 cm/s) with the colour gain increased enough such that normal tissue exhibits rare, scattered colour.[7]

HOW DO YOU INTERPRET POCUS OF THE APPENDIX?

The typical appearance of the normal appendix is an oval or circle in the transverse plane with a maximal diameter of 6 mm,[8] and a blind-ending tubular structure in the longitudinal plane. A normal appendix should be compressible. It can be differentiated from small bowel by the lack of peristalsis and its blind end, from large bowel by its small calibre, and from iliac vessels by their pulsatility and their flow seen with colour Doppler.

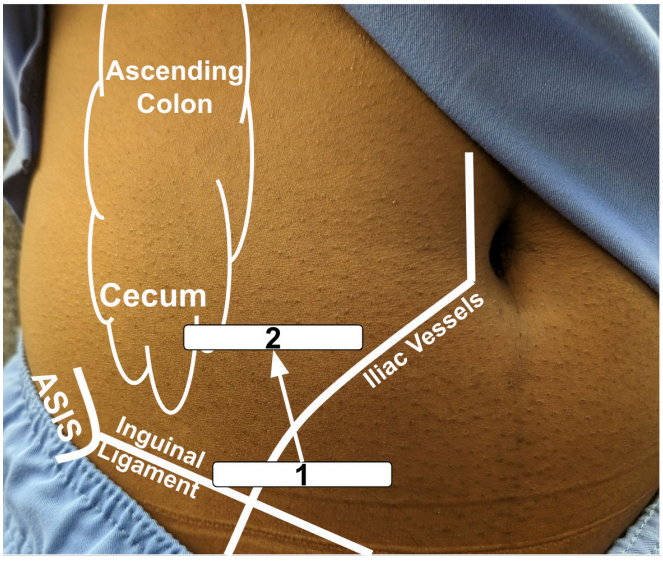

Figure 4 The anatomical method to find the appendix begins with finding the iliac vessels at the inguinal ligament and moving superiorly to identify the cecum. The appendix can often be found medial to the cecum overlying the iliac vessels. Note that graded compression is used throughout the study to displace the bowel.

The diagnosis of appendicitis is made by identifying a non-compressible, non-peristalsing, blind-ended, tubular structure measuring greater than 6 mm in diameter (measured from outer edge to outer edge at its widest point along its length) (figure 1). Secondary signs of appendicitis can also be visualised, including hyperaemia, periappendiceal or pericecal fluid, free fluid, phlegmon, pericecal inflammatory fat changes and an appendicolith.[9–11] Hyperaemia in the wall of the appendix can be visualised with colour or power Doppler.[9 10] As an inflamed bowel wall becomes more oedematous, the distinct layers of the wall become apparent, with hyperechoic layers separated by anechoic layers of oedema, which can help to differentiate an inflamed appendix from other small bowel or iliac vessels.[9 10] Occasionally, an appendicolith can be visualised, which appears as a hyperechoic interface with sonographic shadowing within the appendix similar to the appearance of a gallstone.[10]

WHAT IS THE INTERPRETATION OF THIS PATIENT'S US?

The visualised appendix is a tubular, blind-ended structure (figure 1), 8.4 mm in diameter with multiple layers of oedematous bowel wall visible (figure 2), and is non-compressible and non-peristalsing (not shown). The first online supplemental video 1 traces the appendix from the tip to its origin at the cecum (note the surrounding inflammatory fat stranding). Finally, the image in figure 3 confirms with colour Doppler that it is not a vascular structure. This US is diagnostic for appendicitis.

WHAT IS THE EVIDENCE FOR USING APPENDIX POCUS IN CLINICAL PRACTICE?

POCUS is accurate, rapidly performed at the bedside (less than 10 min[4]), can shorten ED length of stay[5] and can reduce patient exposure to the ionising radiation used in CT.[4 5] Multiple single-centre studies have demonstrated that emergency physician-performed POCUS is specific for ruling in appendicitis and has test characteristics similar to that of radiology-performed US.[12–14] Reported POCUS test characteristics for appendicitis range from sensitivities of 60%–96% and specificities of 68%–97%.[4–6 9 10 15] In two studies that directly compared POCUS to radiology-performed US, the test characteristics were similar.[4 5] In the case of an equivocal study, multiple studies have validated the efficacy of following an indeterminate POCUS with a radiology-performed US or CT to increase accuracy and minimise false negatives.[4 5 16]

POCUS offers several advantages over a radiology-performed US. One study demonstrated the use of POCUS first rather than radiology-performed US or CT reduced ED length of stay by 46% and 68%, respectively.[5] In many facilities, radiology-performed US may not be available during specific hours or may not be present at all. Radiology-performed imaging may also require transfer of a sick patient out of the ED or even to another facility. When compared with radiology-performed US and CT, POCUS may be more affordable for the patient and spares the patient the ionising radiation of CT.[17] Given the high specificity of POCUS for appendicitis, the benefits of early identification and the aforementioned logistical factors likely outweigh the additional time it requires.[4 5 12–14 18]

WHAT ARE SOME EXPERT TIPS WHEN PERFORMING POCUS OF THE APPENDIX?

Finding the appendix is the most challenging aspect of this study. There are three general approaches: (1) placing the transducer on

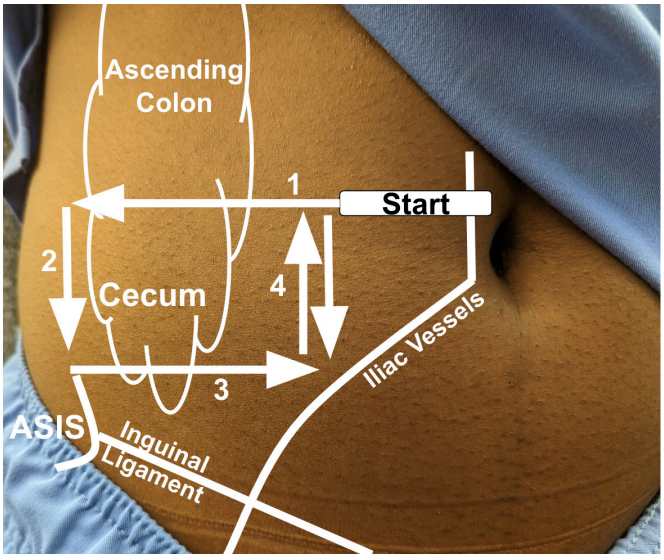

Figure 5 The Sivitz method begins with the probe transverse at the umbilicus. The operator then moves the probe laterally to the lateral border of the ascending colon (1), inferiorly to the end of the cecum (2), medially across the psoas and iliac vessels (3), then up and down along the medial edge of the cecum (4). If unsuccessful, the operator can place the probe in a sagittal orientation over the cecum and move medially across the psoas (not shown). The Anterior Superior Iliac Spine (ASIS) and inguinal ligament are included for anatomical reference. Note that graded compression is used throughout the study to displace the bowel.

the point of maximal tenderness, (2) using anatomical landmarks (figure 4) and (3) the sweeping Sivitz method (figure 5). The anatomical approach used at our institution begins with scanning low in the RLQ in the axial plane near the inguinal ligament until the iliac vessels are identified. Moving superiorly, one can identify the cecum as the first area of air shadowing. The appendix can often be found by systematically searching around in the area of the cecum, especially at the point of maximal tenderness, with graded compression, a technique where increasingly firmer pressure is applied with each patient exhalation such that intervening bowel is pushed aside.[2 6 9] Vascular structures, typically the iliac vessels, can mimic the appendix in the transverse plane, so colour Doppler is useful to differentiate the two.

Sivitz *et al* also recommend the following standardised protocol[12]: 'With the probe initially in the transverse position at the level of the umbilicus and using compression, move laterally to identify the lateral border of the ascending colon. Move down the lateral border to the end of the cecum. Move medially across the psoas and iliac vessels. Move down and up the border of the cecum'. Then, 'with the probe in a sagittal position, identify the end of the cecum in the long axis and move medially across the psoas'. The cecum appears as air shadowing (a hyperechoic line close to the probe with shadowing behind it), whereas small bowel is often fluid-filled, mobile and can be seen peristalsing.

Alternatively, one can simply find the iliacs in the transverse plane in the RLQ and follow them superiorly and inferiorly looking for a blind-ended tubular sac draped over them.

WHAT ARE SOME PITFALLS OF PERFORMING APPENDIX US?

The most significant pitfalls are the inability to locate the appendix, mistaking the small bowel for a dilated appendix, mistaking vascular structures for the appendix (mitigated by the use of colour Doppler), difficulty displacing bowel gas by graded compression, and prematurely excluding perforated appendicitis when the appendix cannot be visualised.

INABILITY TO LOCATE THE APPENDIX

Even with the use of the aforementioned protocols, visualising the appendix can be challenging. In fact, non-visualisation of the appendix may be the most probable outcome. Multiple studies have documented non-visualisation rates from 29% to as great as 54% to 73% in larger studies, even when US technicians acquire the images.[11 12 15 19–21] Several factors make identification of the appendix difficult, including the sonographic shadowing from surrounding bowel gas, the absence of clear delineation between distinct loops of bowel, and the multiple possible orientations of the appendix (eg, retrocecal). Given these difficulties, an extended search may be necessary, so adequate analgesia is essential to allow the patient to tolerate the study without premature termination. Increased body mass index may also influence visualisation of the appendix. While some studies have argued that increased body mass index increases the rate of indeterminate US studies, other studies have found no such effect.[12 21 22] Fortunately, there is some evidence that in the right clinical context, a study without a visualised appendix that also has no secondary signs of appendiceal inflammation has a high negative predictive value.[11 19 21 23] Importantly, however, non-visualisation may also signify appendiceal perforation. As previously mentioned, if there is concern for appendicitis, an equivocal study should be followed by a radiology-performed US or cross-sectional imaging.

MISTAKING THE SMALL INTESTINE FOR THE APPENDIX

A common cause of false-positive POCUS of the appendix is the misidentification of the small bowel as a dilated appendix. For this reason, it is essential that the appendix be thoroughly visualised in the long axis and confirmed to have a blind end. Additionally, the small bowel can often exhibit peristalsis, which will not be present in the appendix.

CASE CONCLUSION

The patient was diagnosed with acute appendicitis by POCUS, which significantly accelerated his disposition since no US technicians were in-house at the time of his presentation. Surgery was consulted and the patient was admitted within an hour of the initial POCUS in the late evening with a plan for appendectomy the following morning. The patient was made nil per os and given antibiotics and pain control. Since the patient was stable early in the course of his illness and could not be scheduled for surgery until the following day, the surgical team opted to corroborate the POCUS findings with an attending radiologist interpretation prior to operating, necessitating a radiology-performed US. The radiology-performed US corroborated the diagnosis with findings of a dilated appendix 10 mm in diameter, with associated hyperaemia and recruited periappendiceal fat. No appendicolith was visualised. Later that afternoon, the patient had an unremarkable laparoscopic appendectomy and was discharged home the next day.

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