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Can Ultrasound With Contrast Enhancement Replace Nonenhanced Computed Tomography Scans in Patients With Contraindication to Computed Tomography Contrast Agents?

Summit Sawhney, MD* and Stephanie R. Wilson, MD*†

Purpose: Our purpose is to determine the efficacy of ultrasound (US), with the addition of contrast enhancement (CEUS), in the identification and characterization of abdominal pathology compared with nonenhanced computed tomography (CT) scan (NECT).

Methods: This prospective cohort study recruited 197 patients with NECT, the majority with renal failure, to have US, with addition of CEUS, if focal pathology was detected, occurring in 145 patients. Nonenhanced CT scan, US, and CEUS images/video files were presented to 2 blinded readers, in anonymous order. Examination quality and positive observations were recorded. True diagnosis was determined with pathology, follow-up imaging, and clinical notes. Data analysis showed sensitivity of NECT and US in the identification and characterization of pathology and sensitivity of CEUS to characterize abnormalities.

Results: Most pathology involved liver (n = 87), kidney (n = 35), and peritoneum (n = 13). Ultrasound alone was superior to NECT in the identification of hepatic and renal pathology, with both performing poorly at characterization. With addition of CEUS, characterization of hepatic and renal pathology reached 100%. Nonenhanced CT is superior to US in identification of peritoneal pathology, especially in large patients. Further solid and hollow organ pathology identified and characterized was of insufficient size to draw conclusions.

Conclusions: Nonenhanced CT has limited ability to identify and characterize solid and hollow organ pathology. Ultrasound with the benefit of CEUS is superior to NECT in the characterization of focal liver, kidney, and peritoneal pathology. Contrast-enhanced ultrasound outperforms NECT in evaluation of suspect abdominal pathology in those with renal failure.

Key World: contrast-enhanced ultrasound, nonenhanced CT scan, renal failure

Contrast-enhanced computed tomography (CT) scan, as a cross-sectional imaging study of the abdomen and pelvis, is undoubtedly one of the most commonly ordered tests in any radiology department. The excellent ability of CT scan to identify and evaluate pathology in any of the solid abdominal organs and its perceived ability to rapidly evaluate the solid and hollow organs is a selling point for clinicians and emergency physicians alike. Intravenous (IV) contrast agents are utilized for CT scans to assess blood flow at the tissue perfusion level to the abdominal and pelvic organs and permit characterization of mass lesions in various phases of enhancement.[1] They also increase contrast resolution and aid in identifying and further characterizing solid and hollow organ pathology.

However, the considerable benefits of this imaging modality come at a cost to the patient, including exposure to ionizing radiation.[2] Recent reports published in medical journals[3] and mainstream newspapers[4] have claimed that "CT radiation may cause cancer." In particular, CT of the abdomen and pelvis is reported to cause the highest number of additional cancers in the United States (14,000 additional cancer cases a year in the United States related to scans of the abdomen and pelvis).[4]

In addition to ionizing radiation, further risk to patients at the time of contrast-enhanced CT relates to the use of contrast agents, which are nephrotoxic and can elicit a wide range of allergic reactions.[5,6] Nephrotoxicity associated with the injection of CT contrast agents may occasionally occur in healthy individuals and more commonly in those with borderline renal function. Therefore, iodinated contrast medium has a very limited role in patients with underlying renal failure. At our institution, when such a patient arrives for his/her enhanced CT examination of the abdomen and pelvis, the study is often performed without IV contrast and deemed a nonenhanced CT scan (NECT). In our institution, this occurs in 1 of every 150 patients on whom abdominal-pelvic CT scan is performed. Furthermore, NECT is shown to be useful for a short list of indications, including attainment of gross anatomical information, assessment for renal calculi, and identification of intra-abdominal ascites/hemorrhage; however, it is limited in its identification of focal organ pathologies. In addition, NECT scans are performed at lower mAs than enhanced CT of the abdomen and pelvis, which yields poor image quality, in an already limited examination.

Ultrasound is a safe and readily available imaging modality that can also assess the abdominal and pelvic viscera. Used

with color Doppler imaging, accurate information can be acquired about the organ structure and the blood flow within the large abdominal vasculature. However, it is the addition of contrast-enhanced ultrasound (CEUS) that improves the performance of US to allow for characterization of solid organ pathology.[7,8] Contrast-enhanced ultrasound utilizes microbubble contrast agents and specialized imaging techniques to demonstrate blood flow at the tissue perfusion level.[9] In our institution, we use Definity (Lantheus Medical Imaging, Billerica, Mass). The microbubble contrast agent is composed of a tiny bubble of perfluorocarbon gas with a protective lipid shell. They have a strong safety profile[10] and can be used in patients irrespective of their renal function. Furthermore, CEUS does not expose the patient to ionizing radiation. Conventional ultrasound (US) provides gray-scale, color Doppler, and spectral information and is useful in assessing large vessels with high-velocity flow. However, the ability to detect perfusion at the tissue level and therefore characterize mass lesions is limited with the use of color Doppler alone. With the addition of microbubble contrast agents and utilization of additional techniques to suppress the signals arising from the background tissue, CEUS allows visualization of high- and low-flow blood pool patterns at the microcirculatory level in any phase of arterial and venous enhancement. Therefore, an inherent advantage of CEUS is its dynamic nature and ability to assess contrast enhancement patterns in real time, and within any and all phases of enhancement, all the while providing higher temporal resolution than other modalities. Furthermore, administration can be repeated because of the high safety profile of CEUS.

Today, CEUS is established for the characterization of focal liver masses, and this comprises the approval indication for microbubble contrast agents in most jurisdictions.[11–13] Increasingly, however, the indications and applications increase including characterization of focal masses in virtually all organs accessible for US,[9,14,15] determination of disease activity in inflammatory bowel disease,[16] and for monitoring response to antiangiogenic therapies in oncology.[17,18]

Computed tomography and magnetic resonance imaging (MRI) rely on the injection of predetermined volumes of contrast agents and predefined scan time points or bolus tracking for imaging acquisition in various phases of enhancement, which inevitably leads to errors and confusion on the exact phase of enhancement captured. One of the main indications for enhanced CT or MRI examinations is to evaluate the enhancement characteristics of focal lesions. Contrast-enhanced ultrasound is able to assess the same enhancement and washout characteristics, without requirement for iodinated or gadolinium contrast agents, which have a proven nephrotoxic effect, and most importantly without the use of ionizing radiation.[19,20] Research has shown that liver mass characterization is the most established and successful indication for CEUS.[11–13]

Nonenhanced CT suffers from severe performance compromise on the basis of reduction of tissue contrast while maintaining its risk from radiation. The purpose of this study was to evaluate the use and efficacy of US, with the addition of CEUS, in a consecutive population of patients receiving an NECT. We hypothesize that US, with the benefit of CEUS, is superior to NECT in characterization of solid and hollow organ pathology.

METHODS

This prospective study has institutional review board approval. All patients provided signed informed consent.

A total of 197 stable adult patients undergoing an NECT at our institution were eligible for recruitment for our study. All recruited patents had a conventional baseline sonogram and, when clinically appropriate, also CEUS for characterization of identified solid organ pathology (n = 145). There were 79 women and 118 men, with an age range of 50 to 70 years. The majority of patients had their US/CEUS prior to their NECT as they were recruited based on the patient lists of those booked for NECT at our institution. The reasons for NECT include the following: abnormal renal function as defined by a serum creatinine greater than 130 μmol/L (n = 109, 55%), assessment for renal stones, CT KUB (kidneys, ureters, bladder) (n = 38, 19%), allergy to IV contrast (n = 18, 9%), other imaging that include an NECT (n = 14, 7%), and unknown, including failure to gain venous access at the time of the CT (with successful IV access on the subsequently performed CEUS performed on an alternate day) (n = 18, 9%).

US With CEUS

All recruited patients (n = 197) had a complete conventional baseline sonogram and, when clinically appropriate, also CEUS for characterization of identified solid organ pathology (n = 145, ~75%). The baseline ultrasound was performed on 1 of 4 commercially available US units in our US department. Contrast-enhanced ultrasound was performed with Definity (Lantheus Medical Imaging) and contrast-specific imaging techniques on approved US systems: Philips iU22 (Bothell, Wash), Siemens Acuson Sequoia (Mountain View, Calif), Toshiba Aplio (Tokyo, Japan). Solid and hollow organ pathology identified on the baseline scan was evaluated with CEUS as per our standard daily practice. As in the standard clinical performance of CEUS, multiple injections of agent were given until such time as a complete and satisfactory examination was obtained. Definity is approved for liver mass characterization in Canada. Usage for characterization of other masses in other organs is off label and performed with patient verbal consent.

Nonenhanced CT

The NECT was performed using a 64–multi–detector-row CT dual-source scanner (SOMATOM Definition; Siemens Healthcare, Erlangen, Germany). Scan parameters include 0.6-mm collimation, 120-kVp tube voltage, and 240 to 400 mA. Image acquisition was from the top of the hemidiaphragms to the greater trochanters, with coronal reformat.

Blind Read

Two anonymized image files were prepared for blind review. The first contained the conventional baseline US and CEUS, and the second, the NECT. The US file included the baseline US, saved as static images comprising a complete abdominal study, consisting of the solid and hollow viscera, peritoneal cavity, and vascular structures. Contrast-enhanced ultrasound was saved as both static images of all phases of enhancement and a Windows media file playing at 10 frames per second of the organ being examined to show the arterial phase of the contrast agent to peak enhancement. The NECT files consisted of the NECT in

TABLE 1. Sensitivity of NECT, US, and CEUS in the Identification and Interpretation of Solid/Hollow Organ Pathology

Organ Observed	Total No. of Patients	NECT Identification/ Characterization, %/%	US Identification/ Characterization, %/%	CEUS (Only Interpretation) (%)
Liver	n = 87	67/0	98/9	96
Kidney	n = 35	89/7	100/7	89
Peritoneum	n = 13	92/38	78/31	86
Bowel	n = 11	73/18	100/45	100
Pancreas	n = 7	100/0	100/0	57
Adnexa	n = 5	100/0	100/20	100
Spleen	n = 3	67/0	100/0	33
Bladder	n = 1	0/0	100/0	100

axial and coronal planes, in both soft tissue (W: 440 Hounsfield units [HU], L: 40 HU) and liver/spleen (W: 175 HU, L: 70 HU) windows, saved as a Windows media file that played slowly at 5 frames per second.

Two readers, blinded to all clinical and demographic information, then evaluated these images files independently, with all NECT imaging separated from their corresponding US/CEUS examination. Both readers have more than 5 years of experience in radiology, with regular interpretation of CT scans. Each reader completed a questionnaire for each NECT and US examination, which consisted of the quality of the examination, as well as observations and their subsequent interpretations related to all solid and hollow viscera and the peritoneal cavity. If there was discordance of observation and or interpretations between the 2 readers, this was resolved by consensus discussion between them. Agreement among the readers was calculated with κ value.

Data from the blind read were analyzed to test observation and interpretation of NECT and US/CEUS. Our primary end point was the identification of pathology. The secondary end point was its characterization. Interpretations of findings were compared with a reference standard based on gross pathology and clinical and imaging follow-up data for each patient. Primary malignant tumors of the liver, kidney, pancreas, adnexa, bladder, and bowel were confirmed by pathology. Metastatic lesions did not all have tissue confirmation, although their ongoing growth on imaging studies was most reflective of metastatic disease. For each modality, true-positive observation meant a true lesion was correctly identified, whereas a false-negative observation meant a lesion was missed. A false-positive observation meant a lesion was identified when in truth (based on follow-up imaging and use of other imaging modalities) no lesion was present. Accuracy of the characterization of pathology (number of correct diagnosis / total number of diagnoses offered) was then calculated for each modality. The sensitivity of NECT and US in the identification and characterization of solid, hollow, and peritoneal pathology was calculated, along with the accuracy of NECT, US, and CEUS in characterizing pathology detected.

RESULTS

The greatest numbers of pathologies detected were in the liver, followed by the kidney. Pathologies were detected in many other organ systems, as listed in the following sections,

but in a much smaller number of patients, all summarized in Table 1. In each organ system, pathologies detected ranged from benign cysts to metastatic or primary malignant disease, many of which were undetected by the NECT. Table 1 also summarizes the accuracy of NECT, US, and CEUS interpretation of identified pathology. Interreader agreement was high, with a κ value for observations and interpretations being greater than 0.75.

Tables have been provided summarizing the hepatic and renal cases, and the remaining organ systems have been documented in text format as follows.

Liver

There were a total of 87 liver cases. The vast majority of cases were confirmed liver metastasis (32/87), followed by hemangioma (14/87), hepatocellular carcinoma (HCC) (13/87), and focal nodular hyperplasia (9/87). Nineteen of 87 "other" cases were noted, which consisted of focal fatty change (9/87), simple cyst (6/87), abscess (2/87), cholangiocarcinoma (1/87), and lymphoma (1/87). The remaining 4 patients had no liver pathology, despite having been suspected on NECT and/or US. The sensitivity of NECT in identifying liver pathology was 67%. The accuracy of NECT in characterizing liver pathology was 0%. The sensitivity of ultrasound in identifying liver pathology was 97%, with an accuracy of correctly characterizing these pathologies of 7%. The accuracy of CEUS in correctly characterizing liver pathology was 96% (Table 2).

Kidney

There were a total of 35 renal cases. The majority of our patients had proven renal cell carcinoma (17/35), followed by

TABLE 2. Performance of NECT, US, and CEUS in Identifying and Characterizing Liver Pathology

Liver (n = 87)	NECT	Ultrasound	CEUS
TP (detected true pathology)	57	84	
TN (detected true-negative pathology)	0	0	
FN (missed true pathology)	28	2	
FP (detected pathologies that were not present)	2	1	
Sensitivity (identified pathology)	0.67	0.98	
Accuracy (correctly characterized pathology)	0	6 (7%)	81 (96%) (n = 84)

confirmation of benign renal cysts (14/35), metastatic disease to the kidney (2/35), pyelonephritis (1/35), and confirmation of no renal mass (1/35). The sensitivity of NECT in identifying renal lesions was 89%. The accuracy of NECT in characterizing renal lesions was 7%. The sensitivity of ultrasound in identifying renal lesions was 100%. The accuracy of ultrasound in characterizing these renal lesions was 7%. The accuracy of CEUS in correctly characterizing renal lesions was 89% (Table 3).

Peritoneum

There were a total of 13 peritoneal cases. The majority of our patients had confirmed peritoneal metastasis (8/13, 62%), followed by hematoma (3/13, 23%), lymphoma (1/13, 7%), and abscess (1/13, 7%). The sensitivity of NECT in identifying peritoneal pathology was 92%. The accuracy of NECT in correct characterization of peritoneal pathology was 38%. The sensitivity of ultrasound in identifying peritoneal pathology was 76%, with accuracy in correctly characterizing peritoneal pathology of 31%. The accuracy of CEUS in correctly characterizing peritoneal pathology was 86%.

Bowel

There were a total of 11 bowel cases. Pathologies confirmed were led by inflammatory bowel disease (5/11, 45%), followed by primary bowel malignancy (2/11, 18%), bowel lymphoma (2/11, 18%), abscess (1/11, 9%), and adhesions (1/11, 9%). The sensitivity of NECT in identifying bowel pathology was 73%. The accuracy in correctly characterizing bowel pathology was 18%. Sensitivity of ultrasound in identifying bowel pathology was 100%. Its accuracy in correctly characterizing bowel pathology was 45%. Accuracy of CEUS in correctly characterizing bowel pathology was 100%.

Pancreas

There were a total of 7 pancreatic cases. Pathologies detected included pancreatic adenocarcinoma (2/7, 30%), serous cystadenoma (2/7, 30%), metastasis (1/7, 14%), and autoimmune pancreatitis (1/7, 14%). There was a single case of normal pancreatic tissue. The sensitivity of NECT in identifying pancreatic pathology was 100%. However, its accuracy in correctly characterizing the pancreatic pathology was 0%. The sensitivity of ultrasound in identifying pancreatic pathology was 100%. However, the accuracy in correctly characterizing the pancreatic pathology was 0%. Contrast-enhanced US accuracy in correctly characterizing pancreatic pathology was 57%.

Adnexa

There were a total of 5 adnexal cases. Pathologies ranged from serous cystadenoma (2/5, 40%), serous cystadenocarcinoma (1/5, 20%), mucinous cystadenoma (1/5, 20%), and a para-ovarian cyst (1/5, 20%). Sensitivity of NECT in identifying adnexal pathology was 100%. However, accuracy in correctly characterizing these lesions was 0%. The sensitivity of ultrasound in identifying adnexal pathology was 100%. The accuracy of ultrasound in characterizing this pathology was 20%. The accuracy of CEUS in characterizing adnexal pathology was 100%.

Spleen

There were a total of 3 splenic cases, 2 splenic metastases, and a single case of a benign splenic lesion. The sensitivity of NECT in identifying splenic pathology was 67%; however, its accuracy in correctly characterizing splenic pathology was 0%. Sensitivity of ultrasound in identifying splenic pathology was 100%; however, its accuracy in characterizing the pathology was 0%. The accuracy of CEUS in characterizing splenic pathology was 33%.

Bladder

There was a single bladder case, which was a confirmed urothelial carcinoma. Nonenhanced CT was unable to detect this and therefore demonstrated a sensitivity of 0% for both identification and accuracy. Ultrasound identified this lesion but was unable to characterize further, yielding a sensitivity of 100% and an accuracy of 0%. Contrast-enhanced ultrasound correctly characterized this vascular tumor as a transitional carcinoma, with accuracy of 100%.

No Focal Pathology

There were a total of 45 cases where no focal pathology was identified on NECT or US, and therefore, no CEUS was performed.

DISCUSSION

The vast majority of CEUS examinations were performed for the assessment of identified hepatic mass lesions on US. Ultrasound in combination with CEUS performed exceptionally well in identification and characterization of focal liver lesions. Most of the liver cases were masses seen on NECT and US that were indeterminate, with a broad differential diagnosis. Ultrasound, however, saw many more lesions than NECT. Contrast-enhanced ultrasound not only confirmed or refuted the presence of a true mass lesion, but also confidently predicted the frequent presence of pseudolesions, related to either focal fatty infiltration or fat sparing. When a true mass was present, CEUS was able to provide a clear distinction between benign and malignant disease, based on enhancement and washout characteristics. Therefore, CEUS was able to correctly differentiate between primary liver malignancy (HCC) and nonhepatocyte malignancy, including liver metastasis, cholangiocarcinoma, and lymphoma. Hepatocellular carcinoma tends to demonstrate slow washout, whereas nonhepatocyte malignancy demonstrates more rapid washout. A representative example, shown in Figure 1, is of an 84-year-old man with increasing abdominal girth and chronic renal failure presenting for NECT. He had no known risk factors for liver

TABLE 3. Performance of NECT, US, and CEUS in Identifying and Characterizing Renal Pathology

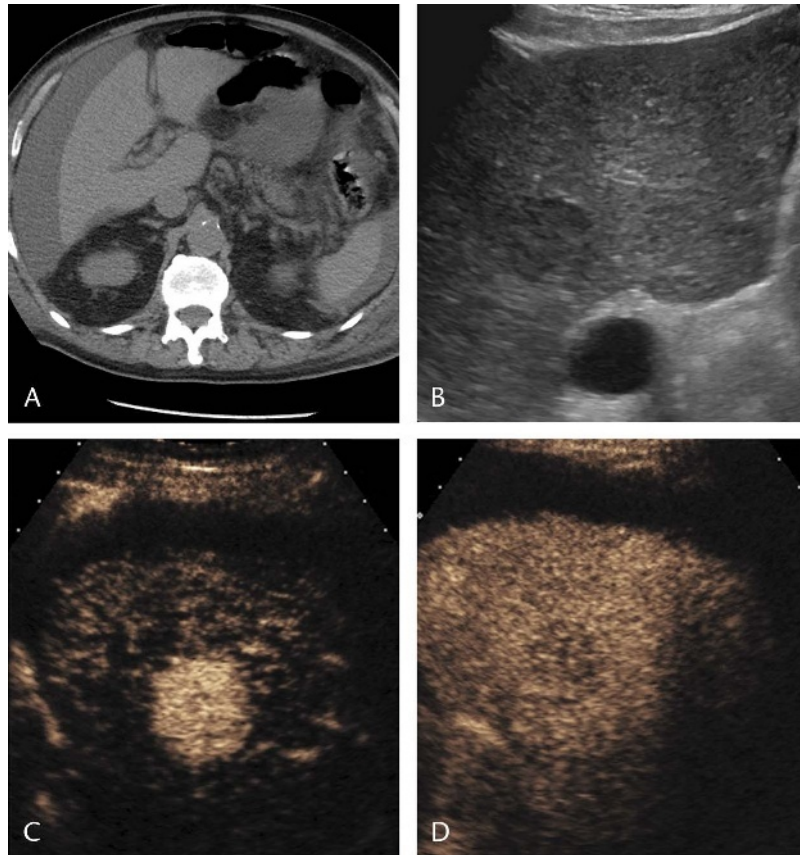| Kidney (n = 35)	NECT	Ultrasound	CEUS
TP (detected true pathology)	31	35	
TN (detected true negative pathology)	0	0	
FN (missed true pathology)	4	0	
FP (detected pathology that were not present)	0	0	
Sensitivity (identified pathology)	0.89	1.00	
Accuracy (correctly characterized pathology)	2 (7%)	2 (7%)	31 (89%) (n = 35)

FIGURE 1. A, Nonenhanced CT performed on an 84-year-old man with renal failure and increasing abdominal girth. There is ascites. The liver is small. There is no focal mass shown. B, There is a focal indeterminate hypoechoic liver mass. C, There is arterial phase hyperenhancement. D, At 5 minutes, there is delayed weak washout, diagnostic of HCC.

disease. An NECT study shows ascites and a liver morphology suggestive of cirrhosis but demonstrated no focal liver lesions. On gray-scale ultrasound, there are morphological features of cirrhosis with a focal hypoechoic mass in segment 4A. Subsequent CEUS shows characteristic arterial enhancement and very delayed weak washout in the portal venous phase, consistent with HCC. Tissue biopsy of the lesion revealed HCC.

Focal renal lesions were the second most common pathology investigated by CEUS. Although NECT performed well in the identification of renal lesions, missing only 4 of 35 (pathology-proven renal cell carcinoma and renal metastasis), it was unable to further characterize the vast majority of lesions it detected. Ultrasound in combination with CEUS demonstrated an accuracy of 89% in characterizing focal renal lesions. We present an unfortunate case of a 35-year-old medical doctor, shown in Figure 2, with an underlying renal cystic condition, possibly multicystic dysplastic kidney. He presented to the emergency department with ongoing right-lower-quadrant pain and received an adnominal ultrasound for query appendicitis. The appendix was not identified; however, innumerable large hypoechoic retroperitoneal lymph nodes were detected, along with multiple renal cysts including a right anterior cyst with high complexity. Scrotal ultrasound performed concurrently revealed no testicular mass lesion. Because of his underlying renal dysfunction, an NECT examination was performed which

redemonstrated the imaging findings on ultrasound, along with a hyperattenuating right renal cyst with a suspicious thickened wall. At this point, the differential diagnosis remained broad. Etiologies entertained included atypical infection versus malignancy, for which the treatment options and clinical outcome are drastically different. Contrast-enhanced ultrasound demonstrated the cystic-appearing lymphadenopathy to be virtually avascular, but, given the sheer number and size, suggestive of pathology (as opposed to being simply reactive). However, within the right renal hyperattenuating cyst, CEUS demonstrated a small enhancing nodule within an otherwise totally cystic lesion, with cystic renal cell carcinoma suggested as the potential diagnosis. Subsequent aspiration of the liquid content from a large retroperitoneal lymph node with evaluation of the centrifuged concentrate confirmed metastatic cystic renal cell carcinoma. Unfortunately, he passed away shortly after these examinations; however, CEUS did play an important role in narrowing the differential diagnosis away from infection and toward malignancy. Contrast-enhanced ultrasound exercised its strength in similar cases of patients with underlying autosomal dominant polycystic kidney disease. Many of these patients receive countless NECT, which demonstrate underlying renal cysts and sometimes hyperattenuating cysts. The differential for this finding is always a complicated renal cyst versus underlying malignancy, given the increased risk of cystic renal cell
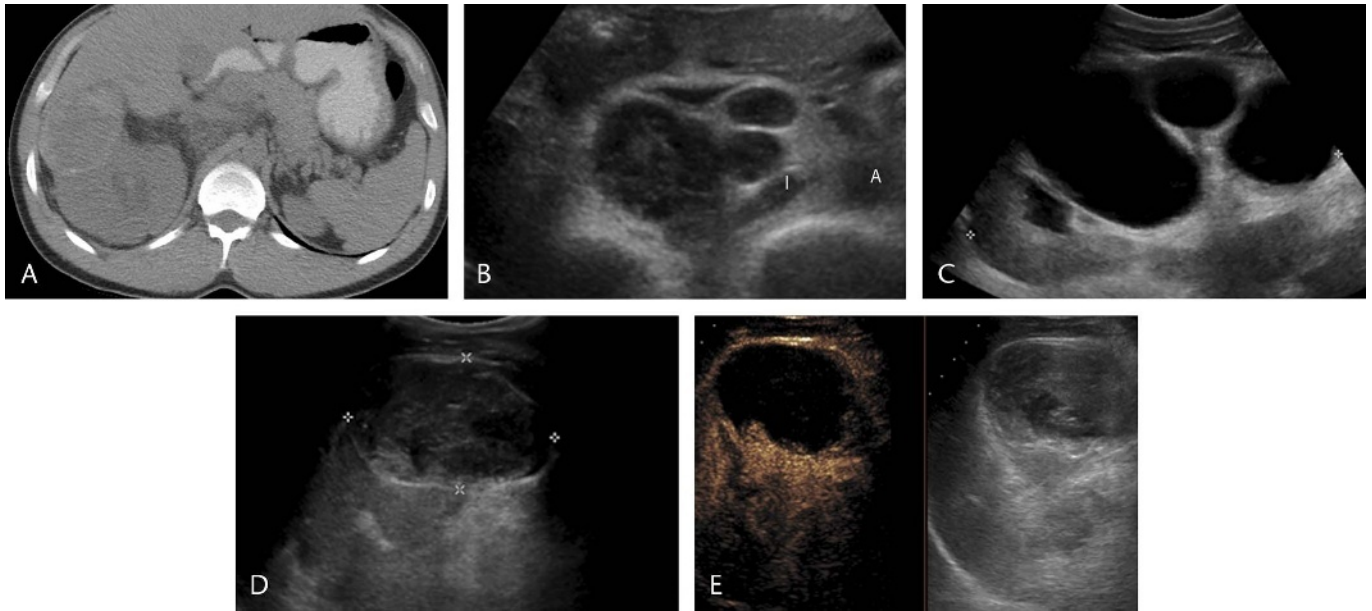
FIGURE 2. A, Nonenhanced CT performed on a 35-year-old man with impaired renal function shows a complex cyst arising from the right kidney, with a thickened wall. The right kidney itself is enlarged. B, An axial gray-scale image of the midline abdomen shows multiple enlarged retroperitoneal lymph nodes, the largest of which appears cystic compared with the smaller, more solid-appearing lymph nodes. C and D, An axial image of the right kidney confirms a large solid and cystic kidney with a dominant indeterminate anterior exophytic mass. E, Contrast-enhanced image of the exophytic mass shown in D shows an enhancing nodule projecting into an otherwise simple cystic mass, concerning for renal neoplasm.

carcinoma. In all of these cases in our study, CEUS quickly demonstrated the hyperattenuating areas to be avascular, ruling out malignancy. In cases outside our study with renal cell carcinoma complicating autosomal dominant polycystic kidney disease, this can be easily confirmed with CEUS. Therefore, as helpful as CEUS is in confirming malignant disease, it is equally as helpful in ruling out malignancy in complex cases.

The sensitivity of NECT and US in identifying adnexal pathology was 100%, although the number of cases was small, n = 5. Contrast-enhanced ultrasound highlighted its strength in accurately characterizing all adnexal pathology, because of its ability to perform dynamic real-time enhancement. A most striking example occurred in a 39-year-old woman, shown in

Figure 3, who had a left renal transplant for end-stage renal disease. She subsequently received an outpatient ultrasound for right-lower-quadrant pain, which demonstrated a large complex left adnexal mass. Nonenhanced CT was performed for attempted further characterization, but the reporting radiologist clearly indicated the difficulty in characterizing this large adnexal mass, given the lack of IV contrast. A broad differential diagnosis was provided that favored the mass represented a urinoma. Fortunately, CEUS was performed, and this exquisitely demonstrated a number of findings. First, the gray-scale images demonstrated a very large (21 × 16 × 12 cm) complex, solid, and cystic mass with thick internal septations and prominent low-level internal echogenic echoes, the latter suggesting the

FIGURE 3. A, Nonenhanced CT performed on a 39-year-old woman demonstrates a large, low-attenuating lesion/fluid collection in the central abdomen, along with a left lower quadrant renal transplant. B, Gray-scale ultrasound image demonstrates a large complex, solid, and cystic mass with thick internal septations and prominent low-level internal echogenic echoes, the latter suggesting the presence of mucin. During real-time imaging, the lesion was felt to arise from the right adnexa. C and D, Contrast-enhanced ultrasound images demonstrate profuse vascularity of the septations and solid components within the cystic mass, strongly suggesting a neoplasm, rather than a fluid collection.

FIGURE 4. A, Nonenhanced CT performed on a 30-year-old man for hematuria and suspected renal colic demonstrates an unremarkable bladder. B, Gray-scale ultrasound image reveals a polypoid lesion arising from the bladder wall. C, Contrast-enhanced ultrasound depicts arterial phase hyperenhancement, concerning for a primary bladder neoplasm.

presence of mucin. Following administration of contrast microbubbles, there was profuse vascularity of the septations and solid components within the cystic mass, strongly suggesting the diagnosis of a neoplasm of mucinous origin, such as ovarian cystadenoma/cystadenocarcinoma, and definitely not a urinoma, or a benign etiology. Subsequent surgical pathology results confirmed this diagnosis. Prior to the CEUS, this patient received countless gray-scale ultrasound studies, as well as 2 unenhanced MRI examinations, all of which were unable to determine the etiology of this mass, which delayed treatment for this young female by at least 2 years.

There was a single bladder case, shown in Figure 4, and despite this being a solitary case, it deserves special attention. The NECT was performed for suspected renal calculi on a 30-year-old man with hematuria and pain, thought to be renal colic. Nonenhanced CT examination was normal. The patient, as part of our study, received an ultrasound, which revealed a polypoid, nonmobile intraluminal bladder mass. Immediately following the ultrasound, CEUS demonstrated avid arterial enhancement of this mass, suggesting malignancy, likely transitional cell carcinoma. Subsequent biopsy revealed low-grade urothelial neoplasm. Without US and CEUS, this young man would have had a longer interval prior to his definitive diagnosis, which was facilitated because of his enrollment in our study. The advantage of the CEUS examination is obvious.

In consideration of the performance of NECT, our study showed clinical scenarios where the choice of NECT seems very appropriate. These include the use of NECT for follow-up in elderly oncology patients, especially if disease is outside the solid viscera. Metastatic renal cell carcinoma, especially when in the retroperitoneum, is only one good example. We fully acknowledge the role of NECT in this and other clinical scenarios, as NECT will demonstrate osseous, pulmonary, and intra-abdominal disease, which can be compared with baseline CT examinations to assess for disease progression. Furthermore, addition of a chest examination, if warranted, makes the choice of NECT an easy one. Nonenhanced CT is also a quick and easily performed examination with little impact from such factors as patient motion.

Ultrasound with CEUS is a proven and established modality for many indications throughout the world. Liver mass characterization is the approval indication for CEUS in most jurisdictions and is therefore its major application, although many other solid organ pathologies have received progressive interest over recent years. Here, we have looked at all organ pathologies in a select population to further advance the choice of this noninvasive and robust technique for characterization of abdominal disease.

In conclusion, US with CEUS is excellent in identifying and characterizing focal solid visceral pathology. Nonenhanced CT identifies less true pathology than US (except for peritoneal disease) and struggles with characterizing the majority of pathology detected. The clinical impact of enrollment in our study, where many patients with malignant pathology in their liver or kidney, in particular, were detected and correctly diagnosed, emphasizes the value of US detection and CEUS confirmation of solid organ pathology in this population. Our recommendation for patients, with a clinical signs suggestive of intra-abdominal disease, is consideration of US with CEUS as an adjunct to NECT, as it provides superior disease identification and characterization with no associated radiation risk. In the population with renal compromise, this should be a particular consideration.

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