A Transesophageal Echocardiography Technique to Locate the Kidney and Monitor Renal Perfusion

Article *in* Anesthesia and analgesia · March 2013

DOI: 10.1213/ANE.0b013e31827ab3b1 · Source: PubMed

5 authors, including:

Saikat Banerjee
Fortis Hospital, Anandapur, Kolkata
10 PUBLICATIONS **33** CITATIONS

A Transesophageal Echocardiography Technique to Locate the Kidney and Monitor Renal Perfusion

Saikat Bandyopadhyay, MBBS, DA, MD, FCCM, Ratan Kumar Das, MBBS, MS, MCh, Abhijit Paul, MBBS, DA, MD, Kalyan Sundar Bhunia, MBBS, DNB, and Deeptarka Roy, MBBS, MD

Monitoring the renal arterial Doppler flow velocity indices, the resistive index and pulsatility index, with ultrasound may help predict renal dysfunction. However, such monitoring has been done intermittently by transcutaneous ultrasound in the postoperative intensive care setting. In the operating room, transesophageal echocardiography (TEE) is an alternative to transcutaneous ultrasound for obtaining indices of renal perfusion. However, it is difficult to locate the right kidney using TEE. We propose a new technique to locate the left kidney that, in our experience, is simple and easy to perform. We believe, starting from a transgastric left ventricular short-axis view, turning left to locate the abdominal aorta, and following it to the origin of the left renal artery may help locate the left kidney faster than previously described techniques. We also propose a new technique to monitor these Doppler indices using TEE during the intraoperative period. (Anesth Analg 2013;116:549–54)

The search for clinical markers to detect and monitor acute kidney injury (AKI) as early as possible has been the focus of interest of investigators all around the world. The predictive value of serum creatinine, the most widely used variable to monitor renal function as an early marker of AKI, is rather poor.[1]

The ultrasound assessment of renal artery flow has been shown to be highly sensitive and specific in the early detection of AKI.[2,3] On the basis of Doppler measurements of renal artery velocities, the resistive index (RI) is calculated as: RI = (peak systolic velocity – minimum diastolic velocity)/peak systolic velocity; and the pulsatility index (PI) is calculated as: PI = (peak systolic velocity – minimum diastolic velocity)/mean velocity.[4]

These indices are associated with resistance to flow distal to the point of measurement, with a higher value indicating increased resistance.[2] However, they are affected by several interrelated variables (Table 1). The range of values of RI and PI in normal subjects is approximately 0.64 to 0.70[4,10] and 0.93 to 1.25,[4] respectively. Bossard et al.[3] recently reported that RI values >0.79 measured postoperatively in cardiac surgical patients predicted the onset of AKI, with values >0.83 predicting the need for dialysis. It may be worthwhile monitoring these indices in patients undergoing cardiopulmonary bypass having a higher risk of AKI (e.g., valvular surgery, prolonged bypass times, age >65 years)[11] and those with preexisting comorbidities (e.g., decreased left ventricular ejection fraction, diabetes, borderline renal function).[12]

Most of the studies assessing these indices were done using transcutaneous ultrasound, which is not feasible to perform in the operating room. Transesophageal echocardiography (TEE) is an alternative.

We present a technique to image the left kidney and measure the RI and PI with TEE. As reported by Yang et al.,[13] and consistent with our own experience, imaging of the right kidney is difficult because it lies too low inside the abdominal cavity, farther away from the esophagus. We therefore describe a technique to locate the left kidney.

METHODS

Sonography of the Left Kidney: How Does the Normal Kidney Look Using TEE?

It is essential for the inexperienced echocardiographer to be able to identify and differentiate the left kidney from closely related intra-abdominal organs. Figure 1 depicts the anatomical relationship between the left kidney and the related organs. Figure 2 demonstrates the transverse and longitudinal sonographic images of the left kidney in 2 dimensions and with color flow Doppler (CFD).

The Technique

We used a standard ultrasound machine (Philips HD 11 XE; Philips, Bothell, WA), a multiplane TEE probe, and a lower frequency (5 MHz) to better visualize the deeper intra-abdominal organs. Although the left kidney can be located, it may be impossible to obtain adequate images of the renal vasculature using standard cardiac presets. Therefore, a vascular preset becomes an essential prerequisite to ensure optimum visualization of the renal vasculature and allow for automated measurement of RI and PI.

The probe is advanced approximately 30 cm from the upper incisor teeth, and a standard midesophageal 4-chamber view is obtained. Starting from the 4-chamber view, the probe is advanced a further 8 to 10 cm to lead it through the short abdominal part of the esophagus eventually into the stomach and anteflexed to obtain a midpapillary transgastric short-axis (TG SAX) view. The esophagus lies initially along the right side of the descending aorta, then runs in front, and eventually a little left of the aorta. We believe

From the Department of Anesthesiology and Pain Medicine, Department of Cardiothoracic and Vascular Surgery and the Department of Critical Care Medicine, Medica Superspecialty Hospital, Kolkata, India.

Accepted for publication October 8, 2012.

The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.anesthesia-analgesia.org).

Reprints will not be available from the authors.

Address correspondence to Saikat Bandyopadhyay, MBBS, DA, MD, FCCM, D 401 Mayfair Greens, 449 S.N. Ghosh Ave., Narendrapur, Kolkata 700103, India. Address e-mail to drsakiban@gmail.com.

DOI: 10.1213/ANE.0b013e31827ab3b1

Table 1. Factors Known to Increase Resistive Index/Pulsatility Index

Altered physiologic states[3]	Disease conditions[5–9]
1. Vasoconstrictive states, e.g., hypocapnia	1. Chronic renal disease
2. Bradycardia	2. Hydronephrosis
3. Hypotension or hypertension	3. Renal vein thrombosis
	4. Renal artery stenosis
	5. Significant aortic regurgitation

that considerable ease in locating the left kidney occurs if the performer uses a simple maneuver we termed as the corkscrew technique (Fig. 3) (Video 1, see Supplemental Digital Content 1, http://links.lww.com/AA/A498) because of the TEE probe manipulations required to obtain the view. The direction of the turns of the probe to reach the left kidney follow a "corkscrew" pattern using the following steps:

- STEP 1: Obtain a TG SAX view (Point A).
- STEP 2: Turn the probe 90 to 270 degrees toward the LEFT until the SAX view of the descending aorta is imaged. The aorta is imaged anterior to the oval hypoechogenic vertebral body (Fig. 1)—(Point B).
- STEP 3: Advance the probe (4–6 cm) following the aorta to the origin of the left renal artery (Point C). Use CFD to image the blood flow in left renal vessels.
- STEP 4: Following the left renal artery, turn the probe RIGHT 90 degrees until the left kidney is visualized (Point D).

It is important to note that after an approximately 90- to 270-degree turn from TG SAX view, the transducer directly faces the aorta. Following it to the origin of the left renal artery, a turn of the probe to the right will help locate the left kidney. In cases where the origin of the left renal artery (from the aorta) cannot be located, a blind 90-degree right turn with probe advanced 4 to 6 cm beyond Point B may help locate the left kidney.

It is crucial to recognize the spleen and differentiate it from the left kidney. The concave inner border of the spleen comes in relation with the convex outer border of the left kidney. The spleen can be located by turning the probe farther to the right from the position where the SAX view of the left kidney is obtained. The spleen is uniformly hypoechogenic in contrast to the kidney, which has a central echogenic pelvis and hypoechogenic peripheral cortex, surrounded by the brightly echogenic fascia of Gerota and perinephric fat pad (Fig. 1B). In cases in which the echocardiographer experiences difficulty locating the spleen by merely turning the probe to the right, gently withdrawing the probe a few centimeters while turning it to the right may help locate the splenic vessels under CFD, which can be traced up to the splenic hilum to locate the concave inner border of the spleen.

The probe is finely adjusted until a clear image of the left kidney is obtained. CFD (Nyquist limit 15–20 cm/s) is used to visualize the renal vasculature. The kidney being one of the most vascular organs clearly stands out when CFD is used. Placing a CFD over the mid portion of the kidney body and varying the probe angle (0–30 degrees) may help visualize both the aorta and the left kidney simultaneously (Video 2, see Supplemental Digital Content 2, http://links.lww.com/AA/A499). Approximately 10% to 30% of individuals have multiple renal arteries (most common occurrence being another additional vessel) on each side.[14] On reaching the hilum, the main renal artery divides into segmental branches that give rise to the interlobar arteries that divide again forming the arcuate arteries at the corticomedullary junction. The arcuate arteries traveling across the renal pyramids give rise to the interlobular arteries (Video 3, see Supplemental Digital Content 3, http://links.lww.com/AA/A500). With experience, one may be able to distinguish the branches from the main renal artery taking into consideration the relative size, order, and sequence of the branching. Once a clear view of the vessels is obtained,

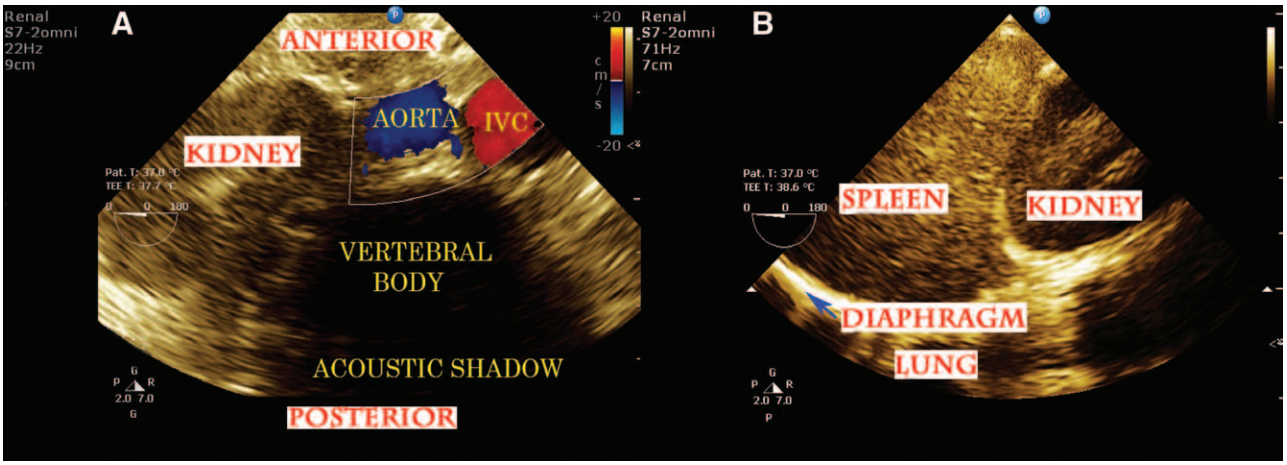


Figure 1. A, The figure demonstrates the anatomical relationships of the left kidney, aorta, inferior vena cava (IVC), and the vertebral body. The vertebral body appears as a hypoechogenic transversely oriented oval structure. The left kidney is seen left and lateral to the vertebral body, aorta just anterior, and the IVC anterolateral to it. The vertebral body creates an acoustic shadow. The 2 round structures at this depth (aorta and IVC) can be differentiated by: (1) their relative position, and (2) Doppler tracing (pulsed-wave Doppler). B, Lateral to the convex-shaped left kidney is the concave inner border of the spleen. The 2 organs have different echogenicity: the kidney has a brightly echogenic central zone (pelvis) in contrast to the hypoechogenic peripheral cortex, whereas the spleen is uniformly hypoechogenic. A modest right turn of the probe from the view seen in (A) may help obtain the view seen in (B).

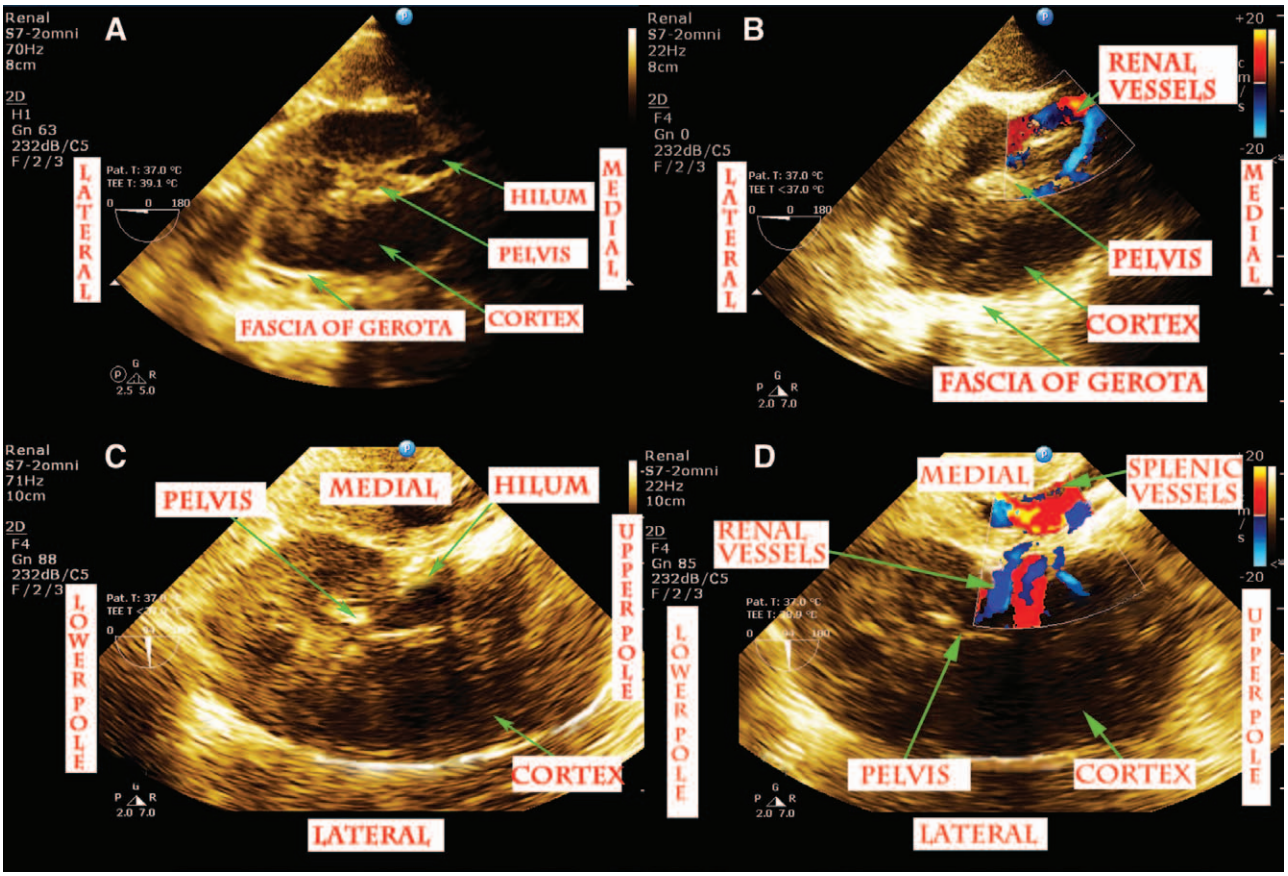
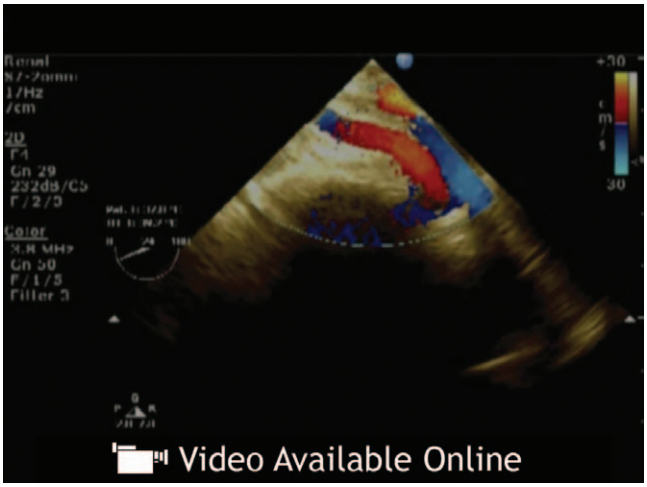


Figure 2. A, The convex outer border of the left kidney at transverse plane (multiplane angle at 0 degrees) is C shaped. The peripheral cortex has a grainy texture and is surrounded by strongly echogenic fascia of Gerota and perinephric fat pad. The central aspect consisting of the calyces, pelvis, and renal sinus fat is more echogenic than the cortex. B, A color Doppler flow sector is placed on the hilum to visualize blood flow. C, The left kidney at longitudinal plane (multiplane angle at 90 degrees) appears "football" shaped. The hilum is seen facing the transesophageal echocardiography transducer. The upper pole lies to the right of the image and the lower pole to the left. D, Placing a color flow Doppler window over the hilum allows visualization of the renal vessels. Occasionally, the splenic vessels may be found lying close to the renal hilum. The splenic vessels lie at right angles to the direction of the renal vessels at the hilum of the left kidney.

Video 1. Steps of the corkscrew technique (see text for description).



Video 2. Aorta (short-axis view), left renal artery, and left kidney. The video demonstrates the course of the main renal artery from its origin (aorta) until it bifurcates into 2 major branches at the hilum of the kidney. The renal vein is seen immediately above and adjoining the renal artery. The vein is slightly larger in caliber (compared with the artery) and appears blue throughout its entire course signifying flow toward the inferior vena cava and away from the probe. Splenic artery can be seen immediately above the renal vein.

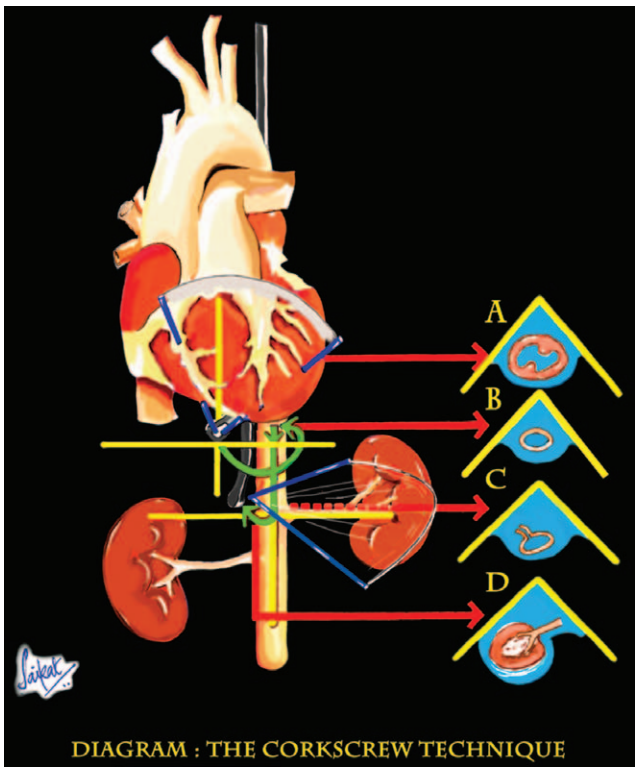


Figure 3. The corkscrew technique (see text for description).

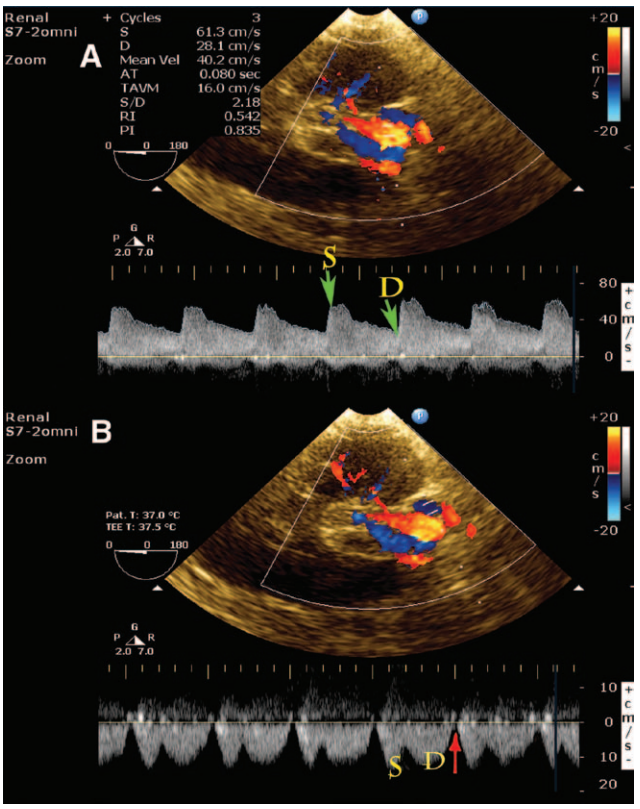


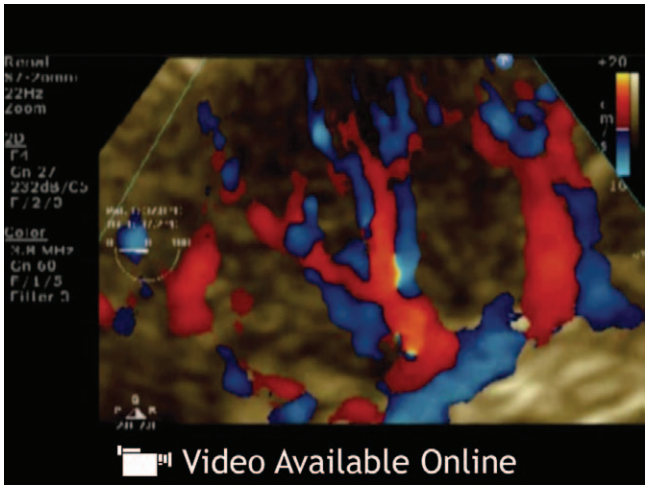
Figure 4. A, The characteristic renal arterial flow velocity pattern recorded with Doppler tracing (pulsed-wave Doppler [PWD]) has a sharp systolic upstroke and diastolic antegrade flow without reversed flow. The highest point of the waveform is peak systolic flow velocity (S) and the trough is the minimum diastolic flow velocity (D). Digitizing and integrating the area under the Doppler flow curves (over 3–5 consecutive cardiac cycles) helps obtain the mean velocity. B, The characteristic biphasic renal venous flow velocity pattern recorded with PWD typically consists of a systolic peak during ventricular systole (S), a diastolic peak (D) during passive filling of the ventricles and a diastolic nadir (red arrow) reflecting atrial contraction.

pulsed-wave Doppler is used to differentiate the main renal artery from the vein 1 to 2 cm before the hilum (Fig. 4).

The cursor is placed on the main renal artery (small gate, 1.2–1.8 mm is preferable) until a clear flow velocity waveform is obtained. When using the vascular preset, activation of the software will automatically trace the spectral Doppler envelopes (Video 4, see Supplemental Digital Content 4, http://links.lww.com/AA/A501) and calculate the Doppler indices RI and PI. In case the automated software is unavailable in the ultrasound platform, the indices may be able to be calculated after manually tracing the Doppler envelopes using the formulae mentioned previously following these steps (Fig. 5):

- STEP 1: Obtain a good quality arterial Doppler flow velocity waveform and freeze it.
- STEP 2: Use calipers to measure the peak systolic velocity (1.13 m/s) and the minimum diastolic velocity (0.250 m/s). Trace the waveform manually to obtain the mean velocity (0.402 m/s).

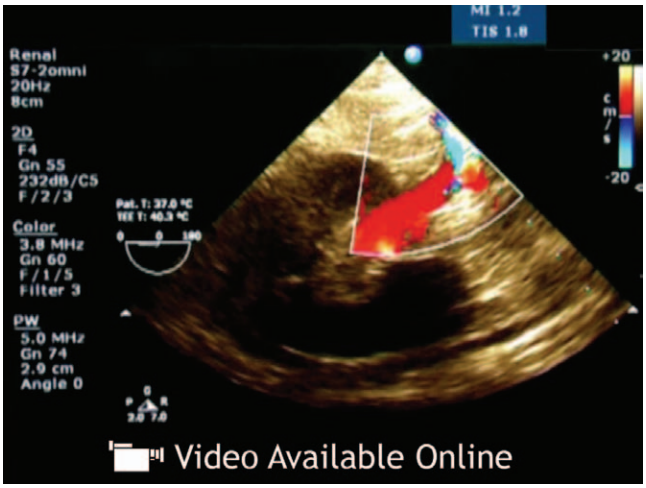
To obtain a mean value, the Doppler indices are measured over 3 to 5 cardiac cycles, and the average value is calculated. The TEE probe can be withdrawn to monitor the cardiac function and can be readvanced to locate the left kidney and renal artery at will. Because the corkscrew technique is simple, relocating the left kidney and continuing renal monitoring should not be difficult.



Video 3. The "typical" renal vascular pattern (see text for description). To have a detailed look at the renal vascular architecture, it is essential to use the "zoom" function and set the Nyquist limit low (15–20 cm/s or even lower, if necessary).

DISCUSSION

Although automated (or manual) calculation of the indices is possible, a few words of caution can help to obtain correct



Video 4. Automated renal perfusion monitoring. Video demonstrating the automated display of the renal Doppler flow velocity indices. A continuous clear flow velocity waveform display is seen here where the individual waveforms are clearly delineated and the shapes and sizes of individual waveforms are similar to each other. The automated tracing (pale blue line) is perfectly aligned along the border of the waveforms ensuring the automated measurements of the flow velocity indices are correct. Mechanical index (MI) and soft tissue thermal index (TIS) displayed on the top right of the screen follow the output display standard recommended by the United States Food and Drug Administration as a measure to ensure safety while monitoring with ultrasound.

measurements and avoid unnecessary errors. It is mandatory to have a clear and continuous display of the velocity waveforms. Too much variability among individual waveforms (e.g., arrhythmias) can lead to error in calculation. Variability is more of an issue when relying on data generated by the automatic tracking system, whereas in the operator-selected waveforms it is up to the operator to choose comparable, similar waveforms. Data can be accepted as correct if the automated tracing of the waveform is perfectly aligned along its margin (Video 4, see Supplemental Digital Content 4, http://links.lww.com/AA/A501). The best way to obtain correct measurements is to ensure good quality waveform display by optimizing depth, adjusting gain, and placing the Doppler gate directly in the center of the renal artery. Although we record the Doppler indices from the main renal artery, these indices convey similar information when derived from branches of the renal artery.[15] It is important to ensure that the measurements are taken from the renal and not from another artery, for example, splenic artery, which can be accomplished by tracing the renal artery from its origin to the hilum before taking Doppler measurements.

There are safety concerns over the prolonged use of Doppler ultrasound.[16] We limit our use of automated monitoring to a few seconds at a time and routinely keep the power at its lowest limits without compromising on image quality. It is not possible to calculate total renal blood flow from a branch artery, but monitoring the Doppler indices may help to closely monitor renal perfusion.

Although the corkscrew technique helps to locate the left kidney with relative ease, locating the left renal artery can be a limiting factor because it may not always be possible to locate its origin from the aorta. Further studies are needed to evaluate the effectiveness of this technique in helping inexperienced echocardiographers locate the left kidney, to assess the intraoperative role of renal perfusion monitoring, and to investigate whether such monitoring has any clear advantage in predicting AKI at the earliest stage. ■

DISCLOSURES

Name: Saikat Bandyopadhyay, MBBS, DA, MD, FCCM.
Contribution: This author helped design and conduct the study, analyze the data, and prepare the manuscript.
Attestation: Saikat Bandyopadhyay attests to the integrity of the analysis and approved the final manuscript.

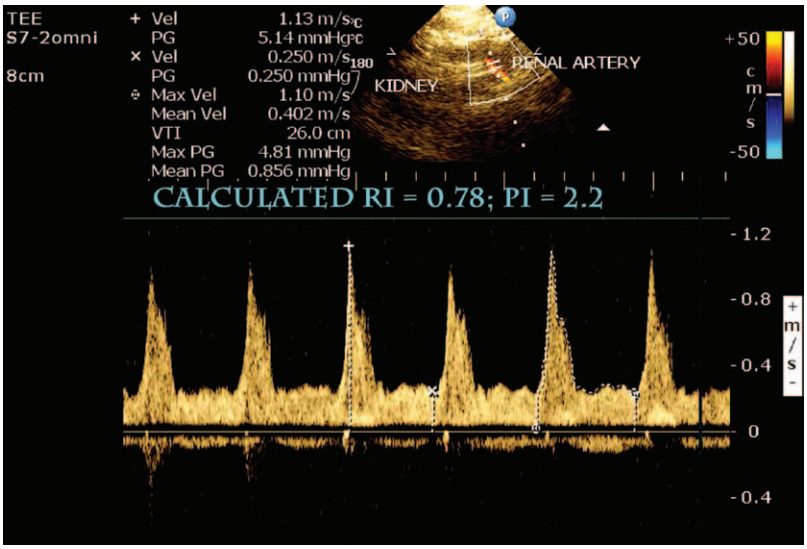


Figure 5. Steps to obtain the indices (resistive index [RI], pulsatility index [PI]) manually using standard cardiac presets. A good quality arterial Doppler flow velocity waveform is obtained and the screen frozen. The calipers are used to measure the peak systolic velocity (1.13 m/s), the minimum diastolic velocity (0.250 m/s), and the waveform traced manually to obtain the mean velocity (0.402 m/s).

Name: Ratan Kumar Das, MBBS, MS, MCh.
Contribution: This author helped prepare the manuscript.
Attestation: Ratan Kumar Das attests to the integrity of the analysis and approved the final manuscript.
Name: Abhijit Paul, MBBS, DA, MD.
Contribution: This author helped prepare the manuscript.
Attestation: Abhijit Paul attests to the integrity of the analysis and approved the final manuscript.
Name: Kalyan Sundar Bhunia, MBBS, DNB.
Contribution: This author helped prepare the manuscript.
Attestation: Kalyan Sundar Bhunia attests to the integrity of the analysis and approved the final manuscript.
Name: Deeptarka Roy, MBBS, MD.
Contribution: This author helped prepare the manuscript.
Attestation: Deeptarka Roy attests to the integrity of the analysis and approved the final manuscript.
This manuscript was handled by: Martin J. London, MD.

REFERENCES

1. Herget-Rosenthal S, Marggraf G, Hüsing J, Göring F, Pietruck F, Janssen O, Philipp T, Kribben A. Early detection of acute renal failure by serum cystatin C. Kidney Int 2004;66:1115–22
2. Darmon M, Schortgen F, Vargas F, Liazydi A, Schlemmer B, Brun-Buisson C, Brochard L. Diagnostic accuracy of Doppler renal resistive index for reversibility of acute kidney injury in critically ill patients. Intensive Care Med 2011;37:68–76
3. Bossard G, Bourgoin P, Corbeau JJ, Huntzinger J, Beydon L. Early detection of postoperative acute kidney injury by Doppler renal resistive index in cardiac surgery with cardiopulmonary bypass. Br J Anaesth 2011;107:891–8
4. Petersen LJ, Petersen JR, Ladefoged SD, Mehlsen J, Jensen HA. The pulsatility index and the resistive index in renal arteries in patients with hypertension and chronic renal failure. Nephrol Dial Transplant 1995;10:2060–4
5. Platt JF, Ellis JH, Rubin JM, DiPietro MA, Sedman AB. Intrarenal arterial Doppler sonography in patients with nonobstructive renal disease: correlation of resistive index with biopsy findings. AJR Am J Roentgenol 1990;154:1223–7
6. Platt JF, Rubin JM, Ellis JH, DiPietro MA. Duplex Doppler US of the kidney: differentiation of obstructive from nonobstructive dilatation. Radiology 1989;171:515–7
7. Kim SH, Byun HS, Park JH, Han JK, Han MC, Lee JS. Renal parenchymal abnormalities associated with renal vein thrombosis: correlation between MR imaging and pathologic findings in rabbits. AJR Am J Roentgenol 1994;162:1361–5
8. Radermacher J, Chavan A, Schäffer J, Stoess B, Vitzthum A, Kliem V, Rademaker J, Bleck J, Gebel MJ, Galanski M, Brunkhorst R. Detection of significant renal artery stenosis with color Doppler sonography: combining extrarenal and intrarenal approaches to minimize technical failure. Clin Nephrol 2000;53:333–43
9. Yang PL, Wong DT. Resistive index may not accurately reflect renal flow resistance in the presence of significant aortic insufficiency. Anesth Analg 2009;109:2033
10. Keogan MT, Kliewer MA, Hertzberg BS, DeLong DM, Tupler RH, Carroll BA. Renal resistive indexes: variability in Doppler US measurement in a healthy population. Radiology 1996;199:165–9
11. Mangos GJ, Brown MA, Chan WY, Horton D, Trew P, Whitworth JA. Acute renal failure following cardiac surgery: incidence, outcomes and risk factors. Aust N Z J Med 1995;25:284–9
12. Conlon PJ, Stafford-Smith M, White WD, Newman MF, King S, Winn MP, Landolfo K. Acute renal failure following cardiac surgery. Nephrol Dial Transplant 1999;14:1158–62
13. Yang PL, Wong DT, Dai SB, Song HB, Ye L, Liu J, Liu B. The feasibility of measuring renal blood flow using transesophageal echocardiography in patients undergoing cardiac surgery. Anesth Analg 2009;108:1418–24
14. Urban BA, Ratner LE, Fishman EK. Three-dimensional volume-rendered CT angiography of the renal arteries and veins: normal anatomy, variants, and clinical applications. Radiographics 2001;21:373–86
15. Taori KB, Chaudhary RS, Attarde V, Dhakate S, Sheorain V, Nimbalkar P, Wasnik PN. Renal Doppler indices in sickle cell disease: early radiologic predictors of renovascular changes. AJR Am J Roentgenol 2008;191:239–42
16. Nelson TR, Fowlkes JB, Abramowicz JS, Church CC. Ultrasound biosafety considerations for the practicing sonographer and sonologist. J Ultrasound Med 2009;28:139–50