KI REPORTS
KIReports.org

Agitated Saline Bubble–Enhanced Ultrasound for Assessing Appropriate Position of Hemodialysis Central Venous Catheter in Critically Ill Patients

To the Editor: Renal replacement therapy is recommended to be initiated immediately in patients with life-threatening acute kidney injury (AKI)–related symptoms. Ultrasound-guided insertion of hemodialysis catheter is recommended for vascular access.[1–3] Agitated saline bubble–enhanced ultrasound is efficient and rapid to ensure the correct positioning of central venous cateter in critically ill patients. Delayed appearance of microbubbles in the right atrium[4] indicates inadequate positioning. A recent retrospective study performed in 202 patients admitted in a dialysis center and undergoing internal jugular catheterization for hemodialysis or medication administration reported that 2 catheter malpositions were detected immediately by agitated saline bubble–enhanced ultrasound.[5]

The primary aim of this prospective study, which was performed in ventilated, critically ill patients with AKI, was to compare agitated saline bubble–enhanced ultrasound with bedside chest radiography for the confirmation of appropriate positioning of hemodialysis catheter. The secondary aim was to compare agitated saline bubble–enhanced ultrasound and bedside chest radiography completion times.

RESULTS

As shown in Figure 1, a total of 99 patients were screened, and 91 were included. Clinical characteristics are shown in Table 1. Vascular accesses were jugular (28 right and 4 left) and subclavian veins (45 right and 14 left). Previous venous cannulation before patients' intensive care unit (ICU) admission, obesity, and proximity of infected abdominal and/or vascular incisions made femoral access impracticable.

Among 84 hemodialysis catheters adequately positioned, 82 were identified by agitated saline bubble–enhanced ultrasound (Figures 2 and 3). All malpositioned hemodialysis catheters were identified by agitated saline bubble–enhanced ultrasound (Figures 4 and 5). The malpositions involved 5 ipsilateral internal

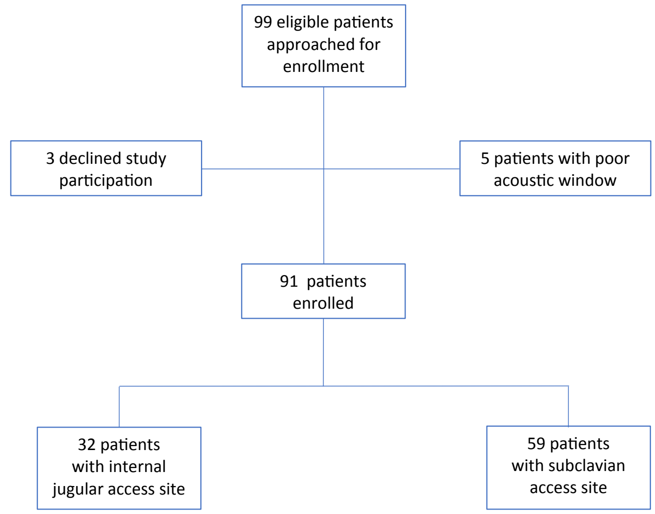

Figure 1. Study flow chart.

Table 1. Patient characteristics

Characteristics	All patients, n = 91	Jugular vein, n = 32	Subclavian vein, n = 59	*P*
Physiological characteristics				
Sex male/female (%)	57/43	63/37	54/46	0.44
Age, yr, mean ± SD	59 ± 13	60 ± 13	58 ± 12	0.45
Body mass index, kg/cm	25 ± 4	25 ± 4	25 ± 4	0.91
SOFA score mean ± SD	11 ± 2	11 ± 2	11 ± 3	0.4
APACHE II mean ± SD	21 ± 6	21 ± 6	19 ± 5	0232
Charlson Comorbidity Index (mean ± SD)	3.7 ± 1.3	3.6 ± 1.3	3.8 ± 1.3	0.55
Outcome dead/alive (%)	15/85	15/85	14/86	0.78
Support of organ failure				
Invasive mechanical ventilation (%)	85	71	83	0.5
Vasopressor support with norepinephrine (%)	82	75	69	0.28
Admission for medical/surgical disease (%)	62/38	65/35	59/41	0.55
Length of ICU stay (d, mean ± SD)	12 ± 3	11 ± 3	6 ± 3	0.6
Cause of acute kidney injury				
Ischemia (%)	12	19	9	0.14
Nephrotoxicity (%)	11	9	12	0.7
Sepsis (%)	32	41	27	0.18
Multifactorial (%)	45	31	52	0.05
Renal replacement characteristics				
Urea level (mmol/l, mean ± SD)	174 ± 13	174 ± 1.1	174 ± 1.9	0.8
Sustained low-efficiency dialysis (%)	43	31	69	0.44
Conventional intermittent hemodialysis (%)	24	45	55	0.24
Continuous venous hemodiafiltration	33	40	60	0.49
Maximal dialysis blood flow (ml/min mean ± SD)	228 ± 18	227 ± 19	228 ± 18	0.92
Insertion catheter attempts	1.5 (0.7)	1.5 (0.82)	1.5 (0.71)	0.89

APACHE, Acute Physiology and Chronic Health Evaluation; ICU, intensive care unit; SOFA, Sequential Organ Failure Assessment.

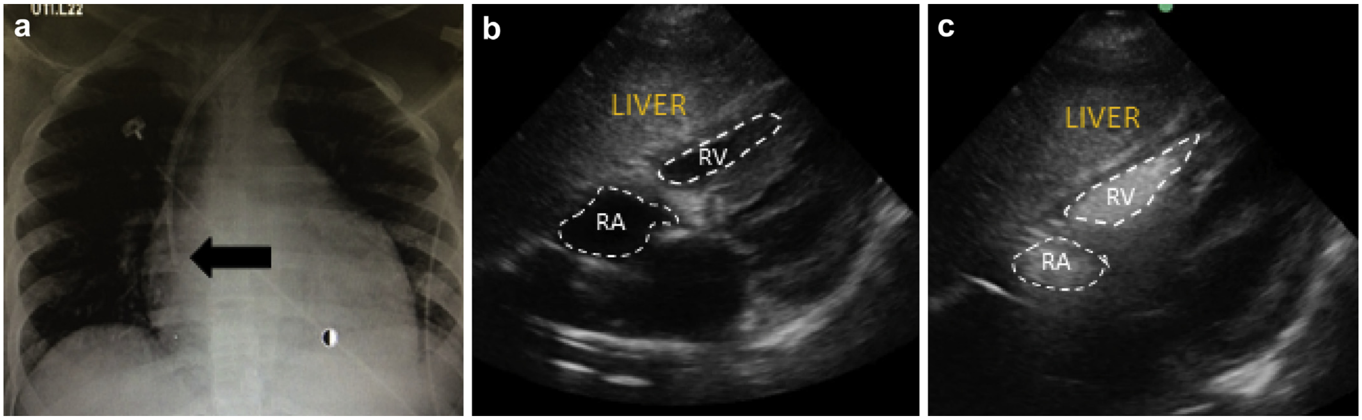

Figure 2. (a) Bedside chest radiograph showing the adequate positioning of the hemodialysis catheter in the superior vena cava (black arrow) after insertion in the left internal jugular vein. (b) Ultrasound subxiphoid view showing right atrium (RA) and ventricle (RV) before the administration of microbubbles through the distal lumen of the catheter. (c) Ultrasound subxiphoid view showing the irruption of microbubbles in the RA and RV 1.5 seconds after their flush through the distal lumen of the catheter. Dynamic views can be visualized in Figure 3.

jugular veins, 1 axillary vein, and 1 innominate vein. Two hemodialysis catheters adequately positioned were not identified by bubble-enhanced ultrasound. In the first patient, a partial vena cava thrombosis was suspected to interfere with microbubble appearance. In the second patient, a pulmonary artery catheter and a central venous catheter were already present in the superior vena cava, and likely partially obstructed the holes of the hemodialysis catheter.

A single intra-atrial position of the hemodialysis catheter was recognized by agitated saline bubble−enhanced ultrasound (Figures 6 and 7). A single pneumothorax was detected by lung ultrasound and confirmed by chest radiograhy. Agitated saline bubble−enhanced ultrasound had a high sensitivity, specificity, and diagnostic accuracy (Table 2), with a κ coeffcient of 0.84.

The average time to confirmation of appropriate hemodialysis catheter placement was 10.5 minutes (95% confidence interval = 9.7–11.3 minutes) by bedside agitated saline bubble−enhanced ultrasound and 133.5 minutes (95% confidence interval = 124.1–142.8 minutes) by bedside chest radiography ($P < 0.0001$).

DISCUSSION

In this prospective study performed in critically ill patients with AKI, agitated saline bubble−enhanced ultrasound was highly accurate in identifying adequate placement of hemodialysis cateter. It was significantly faster than bedside chest radiography.

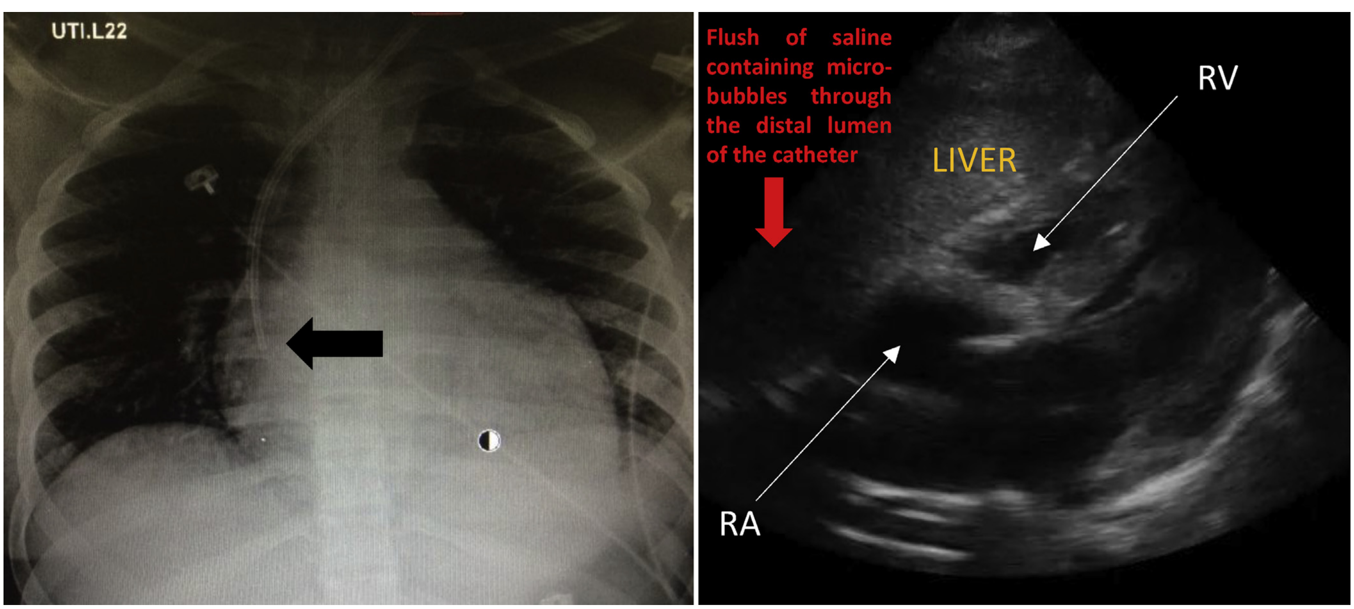

Figure 3. Ultrasound showing irruption of microbubbles in the right atrium and ventricle 1.5 seconds after the injection of saline air mixture (red arrow), attesting to the appropriate position of the hemodialysis catheter (black arrow on frontal chest x-ray).

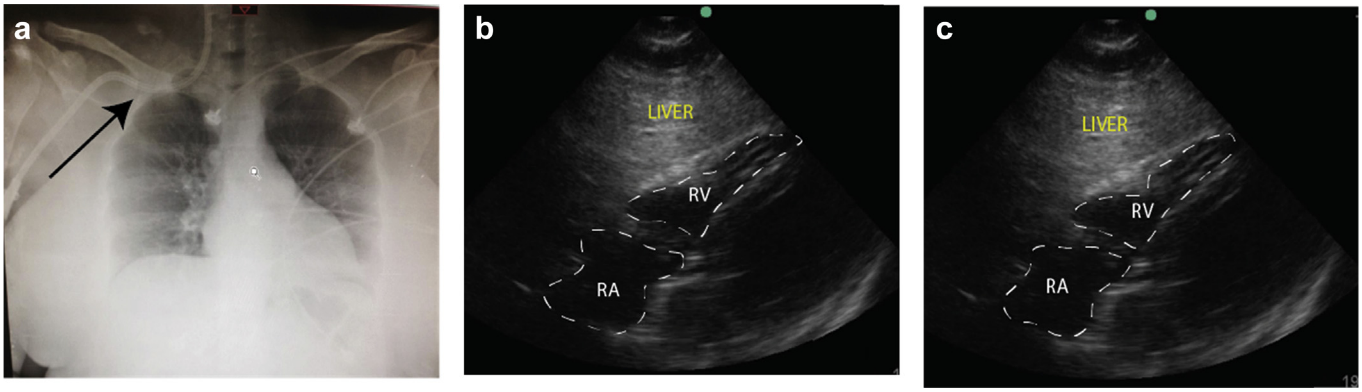

Figure 4. (a) Bedside chest radiograph showing the inadequate positioning of the hemodialysis catheter in the ipsilateral right internal jugular vein after catheter insertion in the right subclavian vein (black arrow). (b) Ultrasound subxiphoid view showing right atrium (RA) and ventricle (RV) before the administration of microbubbles through the distal lumen of the catheter. (c) Ultrasound subxiphoid view showing the absence of microbubbles in RA and RV 4 seconds after their flush through the distal lumen of the catheter. Dynamic views can be visualized in Figure 5.

The use of ultrasound guidance for the placement of central venous catheters in critically ill patients is recommended.[2,3,6,7] This recommendation applies to critically patients requiring placement of a hemodialysis catheter for grade 3 AKI. Given the presence of a sonographer during catheter insertion, it is logical to use ultrasound for assessing adequate positioning at the end of the procedure. There are 2 contrast-enhanced ultrasound methods for assessing correct positioning of central venous catheters. The first is based on the rapid flush of saline through the catheter.[8] Correct positioning is detected as an immediate (≤2-second) echogenic turbulent flow pattern within the right atrium. Color Doppler imaging improves flow turbulence detection.[9] Three prospective studies reported a sensitivity of 75% and a specificity of 100% for assessing inappropriate catheter positioning compared to bedside chest radiography.[10–12] The second method, based on the rapid flush of a saline—air mixture through the inserted catheter, is more sensitive.[4,5] Correct catheter positioning is detected as the appearance within 2 seconds of multiple micobubbles in the right atrium. Incorrect positioning is detected as the lack of or delayed appearance of these microbubbles. The present study confirms the high sensitivity (99%) and specificity (100%) of the technique for assessing appropriate hemodialysis catheter placement.

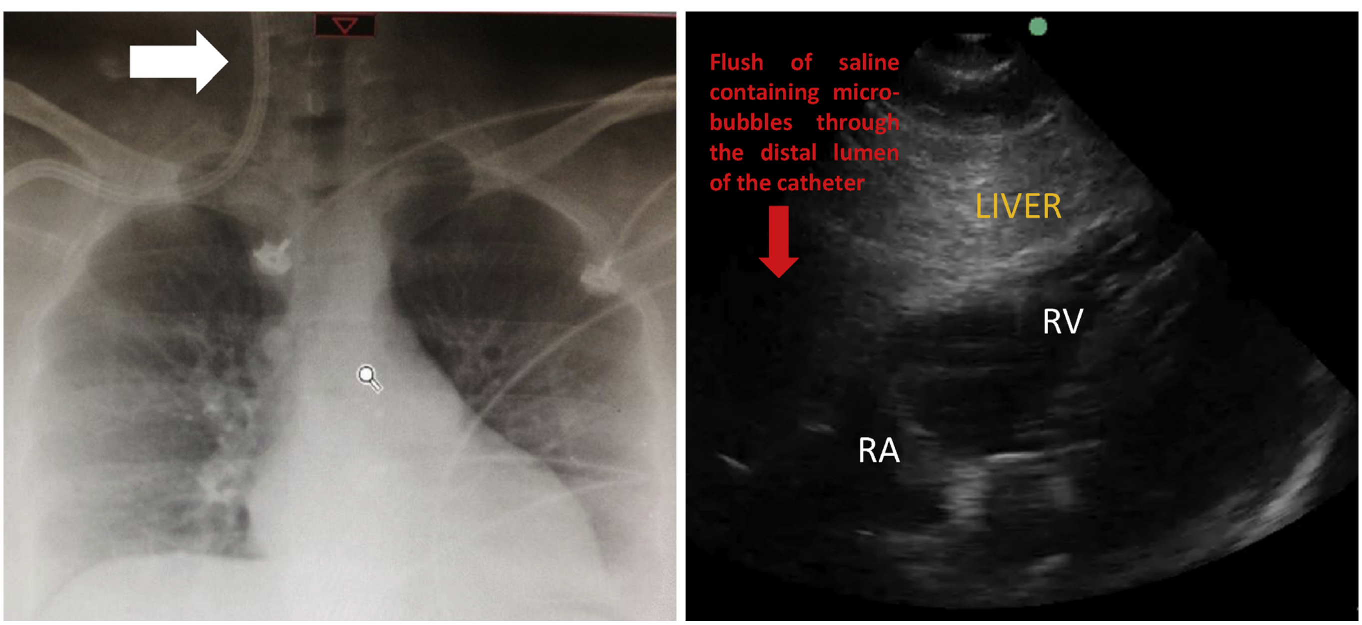

Figure 5. Ultrasound showing no irruption of microbubbles in the right atrium (RA) and ventricle (RV) after the injection of saline air mixture (red arrow), attesting to the innappropriate position of the hemodialysis catheter in the right internal jugular vein (white arrow on frontal chest x-ray).

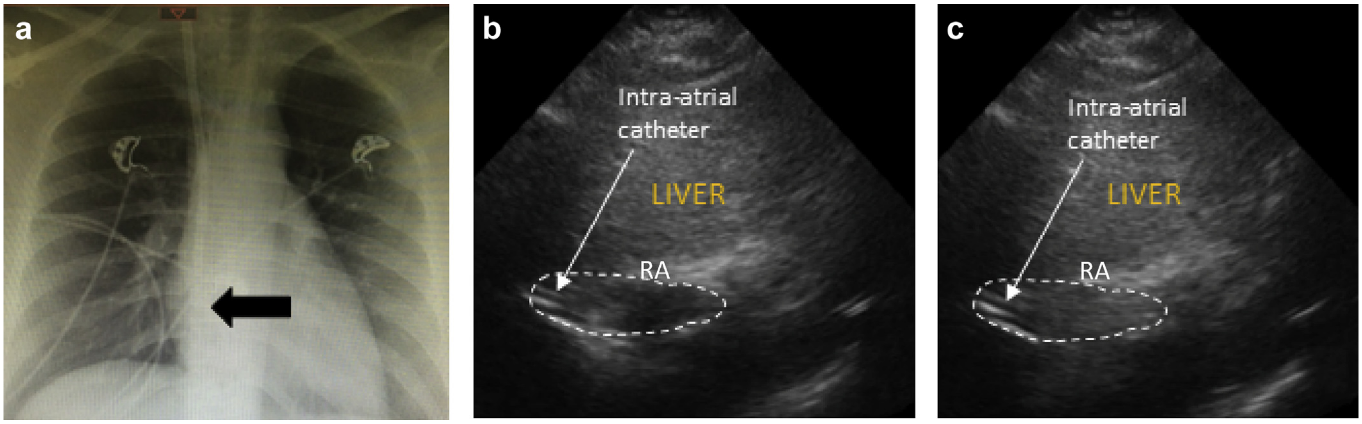

Figure 6. (a) Bedside chest radiography showing the inadequate positioning of the hemodialysis catheter in the right atrium (black arrow) after catheter insertion in the right internal jugular vein. (b) Ultrasound subxiphoid view showing right atrium (RA) and ventricle (RV) before the administration of microbubbles through the distal lumen of the catheter. (c) Ultrasound subxiphoid view showing the absence of microbubbles in RA and RV 4 seconds after their flush through the distal lumen of the catheter. Dynamic views can be visualized in Figure 7.

In addition to easy implementation, agitated saline bubble—enhanced ultrasound avoids radiation exposure for patients and health care workers, and reduces time delay to catheter use. Adequate positioning is required to obtain an appropriate blood flow allowing efficient dialysis. In our study, the blood flow rate was considered adequate in every patient (>200 ml/min) after repositioning the 7 malpositioned catheters. Transthoracic lung ultrasound can also accurately detect pneumothorax complicating hemodialysis catheter insertion, questioning the use of routine post-procedure bedside chest radiography.[13]

Our study has several limitations. First, it is an observational single-center study. Second, only hemodialysis catheter positioned in the right atrium could be directly visualized using the subxiphoid 4-chamber view. In fact, the majority of malpositioned catheters are located in the contralateral subclavian vein and/or ipsilateral internal jugular vein.[4] The internal jugular vein can be visualized by ultrasound using short- and long-axis neck planes, whereas the subclavian vein can be visualized using short- and long-axis supra- and infraclavicular approaches.[3,14] Therefore, if, at the end of the procedure, agitated saline bubble—enhanced ultrasound results are negative without evidence of intra-atrial positioning of the catheter tip, then ultrasound examination of subclavian and internal jugular veins that were not punctured should be performed to detect the presence of the catheter.

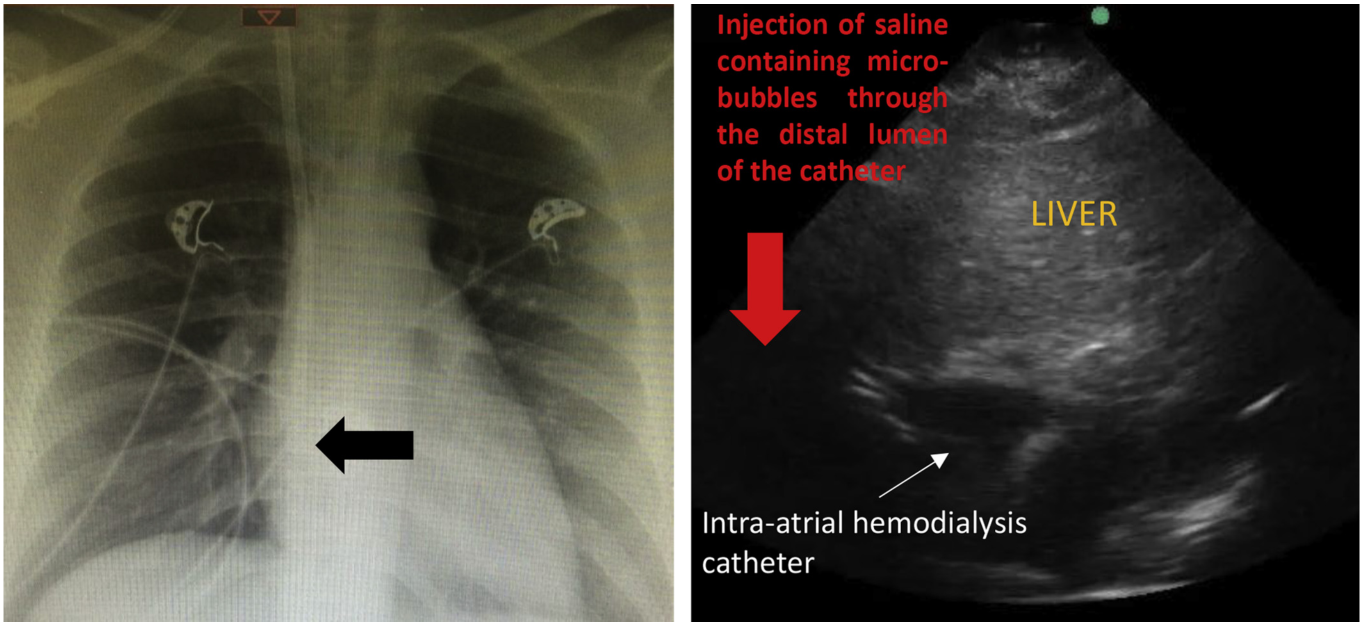

Figure 7. Ultrasound showing the presence of microbubbles immediately after the injection of saline air mixture, attesting to the intra-atrial position of the hemodialysis catheter (black arrow on frontal chest x-ray).

Table 2. Concordance between agitated saline bubble–enhanced ultrasound and chest radiography for identifying appropriate hemodialysis catheter tip positioning

		Chest x-ray+	Chest x-ray−
Agitated saline bubble–enhanced ultrasound+		82	0
Agitated saline bubble–enhanced ultrasound−		2	7
Sensitivity[a] = 98%	Specificity[b] = 100%	Diagnostic accuracy[c] = 98%	

True positive result denotes correct placement of hemodialysis catheter according to bubble-enhanced ultrasound and chest radiography. True negative result = incorrect placement of hemodialysis catheter according to bubble-enhanced ultrasound and chest radiography. False positive result = correct placement of hemodialysis catheter according to bubble-enhanced ultrasound not confirmed by chest radiography. False negative result = incorrect placement of hemodialysis catheter according to bubble-enhanced ultrasound not confirmed by chest radiography.
[a]Sensitivity = (true positive/[true positive + false negative]).
[b]Specificity = (true negative/[true negative + false positive]).
[c]Diagnostic accuracy = ([true positive + true negative]/[true positive + true negative + false positive + false negative).

In conclusion, the dynamic ultrasound visualization of microbubbles in the right atrium was highly accurate to identify adequate placement of hemodialysis central venous catheters and significantly faster than bedside chest radiography. It allowed the immediate start of renal replacement therapy, thereby expediting patient care.

Rogerio da Hora Passos[1,2], Michel Ribeiro[1,2], Julio Neves[3], Joao Gabriel Rosa Ramos[1], Adelmo Vinicius Lima Oliveira[1], Zilma Barreto[1], Rosseane Ferreira[1], Conrado Gomes[1], Paulo Benigno Pena Batista[1] and Jean Jacques Rouby[4]

[1]Critical Care Department, Hospital São Rafael, Salvador Bahia, Brazil; [2]Hospital Português, Salvador, Bahia, Brazil; [3]Critical Care Department, Hospital da Bahia, Salvador Bahia, Brazil; and [4]Multidisciplinary Intensive Care Unit, Department of Anesthesia and Critical Care Medicine Pitie-Salpetriere Hospital, Assistance Publique Hopitaux de Paris, University School of Medicine Pierre and Marie Curie UPMC, University of Paris-6, Paris, France
Correspondence: Rogerio da Hora Passos, Critical Care Physician, Critical Care Department, Hospital São Rafael, Salvador Ba Brazil. E-mail: oiregorpassos@yahoo.com.br

DISCLOSURE

All the authors declared no competing interests.

REFERENCES

1. Frykholm P, Pikwer A, Hammarskjöld F, et al. Clinical guidelines on central venous catheterisation. *Acta Anaesthesiol Scand*. 2014;58:508–524.
2. Lamperti M, Bodenham AR, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. *Intensive Care Med*. 2012;38:1105–1117.
3. Saul T, Doctor M, Kaban NL, et al. The ultrasound-only central venous catheter placement and confirmation procedure. *J Ultrasound Med*. 2015;34:1301–1306.
4. Vezzani A, Brusasco C, Palermo S, et al. Ultrasound localization of central vein catheter and detection of postprocedural pneumothorax: an alternative to chest radiography. *Crit Care Med*. 2010;38:533–538.
5. Wen M, Stock K, Heemann U, et al. Agitated saline bubble-enhanced transthoracic echocardiography: a novel method to visualize the position of central venous catheter. *Crit Care Med*. 2014;42:e231–e233.
6. Liu YT, Bahl A. Evaluation of proper above-the-diaphragm central venous catheter placement: the saline flush test. *Am J Emerg Med*. 2011;29:842.
7. Ablordeppey EA, Drewry AM, Beyer AB, et al. Diagnostic accuracy of central venous catheter confirmation by bedside ultrasound versus chest radiography in critically ill patients: a systematic review and meta-analysis. *Crit Care Med*. 2017;45:715–724.
8. Lanza C, Russo M, Fabrizzi G. Central venous cannulation: are routine chest radiographs necessary after B-mode and colour Doppler sonography check? *Pediatr Radiol*. 2006;36:1252–1256.
9. Weekes AJ, Johnson DA, Keller SM, et al. Central vascular catheter placement evaluation using saline flush and bedside echocardiography. *Acad Emerg Med*. 2014;21:65–72.
10. Gekle R, Dubensky L, Haddad S, et al. Saline flush test: can bedside sonography replace conventional radiography for confirmation of above-the-diaphragm central venous catheter placement? *J Ultrasound Med*. 2015;34:1295–1299.
11. Weekes AJ, Keller SM, Efune B, et al. Prospective comparison of ultrasound and CXR for confirmation of central vascular catheter placement. *Emerg Med J*. 2016;33:176–180.
12. Shieh L, Go M, Gessner D, et al. Improving and sustaining a reduction in iatrogenic pneumothorax through a multifaceted quality-improvement approach. *J Hosp Med*. 2015;10:599–607.
13. Hourmozdi JJ, Markin A, Johnson B, et al. Routine chest radiography is not necessary after ultrasound-guided right internal jugular vein catheterization. *Crit Care Med*. 2016;44:e804–e808.
14. Auyong DB, Yuan SC, Rymer NA, et al. A randomized crossover study comparing a novel needle guidance technology for simulated internal jugular vein cannulation. *Anesthesiology*. 2015;123:535–541.

Received 2 March 2017; accepted 31 March 2017; published online 7 April 2017

Kidney Int Rep (2017) **2**, 952–956; http://dx.doi.org/10.1016/j.ekir.2017.03.010

Renal Involvement in Methylmalonic Aciduria

To the Editor: Isolated methylmalonic acidemia/aciduria (MMA) is a rare metabolic disorder caused by complete or partial deficiency of the enzyme methylmalonyl-CoA mutase (mut^0 or mut^- enzymatic subtype, respectively), a defect in the synthesis or transport of its cofactor, adenosyl-cobalamin (cblA, cblB, or cblD-MMA), or deficiency of the enzyme methylmalonyl-CoA epimerase.[1–5] The clinical spectrum