25 Point-of-Care Ultrasound in the Preoperative Evaluation of the High-Risk Surgical Patient Requiring Urgent Non-cardiac Surgery

Enrico Storti and Michele Introna

Key Points

- High-risk surgery is defined as any surgical operation associated with significant inpatient mortality; despite a considerable research effort, there is still a lack of validated risk assessment tools in the emergency surgery setting.
- Point-of-care ultrasound (PoCUS) consists of bedside ultrasonography used in order to get qualitative answers (e.g., "yes" or "no"), applied in multiple settings and performed by the provider in real-time.
- PoCUS is gaining popularity among clinicians also for perioperative management; its minimal invasivity, cost-effectiveness and rapidity of the clinical answers given bedside, makes PoCUS an ideal technique for preoperative evaluation of patients requiring urgent surgery.
- The ultrasound examination of gastric content provides an individual assessment tool for anesthesia-associated aspiration; the sonographic evaluation of the neck may be performed before securing the airways, but it is also a tool for orienting and monitoring the whole procedure (e.g., checking the proper positioning of an endotracheal tube by lung ultrasound).
- Lung ultrasound is a well-established technique for the diagnosis and management of respiratory distress, also in the surgical population.
- Bedside cardiac evaluation is a powerful tool for guiding fluid resuscitation and for a comprehensive differential diagnosis of the many causes of shock, very common conditions in the perioperative care of patients undergoing urgent surgery.
- The main evidence about the sonographic evaluation of the abdomen in acute care is basically limited to the trauma patients; the Focused Assessment with Sonography for Trauma is a key component of trauma management algorithms worldwide; several authors are also exploring the utility of abdominal ultrasound in the evaluation of the acute abdomen also in the non-traumatic setting (e.g., differential diagnosis of non-traumatic abdominal pain).
- The PoCUS can be understood as a tool that is able to give an idea of the operational margin available to reduce risks and optimize the residual functional reserve. Its intrinsic characteristic of being fast and reliable makes it ideal for the constant assessment of the clinical items involved.

25.1 Introduction

In the era of big data and artificial intelligence, there is still debate in the perioperative sciences community regarding the precise definition of high-risk surgery [1, 2]. High-risk surgery is defined as any surgical operation associated with a predicted inpatient significant mortality, historically set at more than 5% [3]. Accordingly to the 2018 Royal College of Surgeons of England key recommendations, surgical patients should have their risk of morbidity and mortality assessed and recorded, to inform the process of care [4]. Although multiple tools of risk assessment have been validated for use in a "real-life" environment, few of them are specifically tailored for their use in the emergency surgery setting [5].

The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) Classification of Intervention assigns the most urgent surgical scenarios to the first two categories of intervention (NCEPOD-1 and NCEPOD-2), called, respectively, immediate and urgent surgery. The target time to the theatre is considered to be around minutes of a decision to operate in the case of a NCEPOD-1, otherwise around hours in the case of an NCEPOD-2 [6].

Emergency surgery carries, therefore, a higher risk of postoperative morbidity and mortality, due to the disadvantage of being generally exerted on physiologically deranged individuals with limited preoperative information and within a short time frame for management [7]. All the interventions aimed to rapidly correct the physiological derangement and

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inform the surgical team regarding diagnosis, risk assessment and intraoperative management are key elements in this process [8]. Considering this, PoCUS appears as a very promising tool in the urgent surgery setting, due to the time-dependent nature of its management. The term PoCUS includes every use of ultrasound tool, at the patient's bedside, in order to get qualitative answers ("yes or no") in a short amount of time. Extensively adopted in critical care and emergency medicine protocols, PoCUS is still growing as a suitable technique for the preoperative assessment of patients [9].

In the past years, there has been an increase in the interest to include PoCUS in the core curriculum of perioperative medicine, regardless of the medical specialty of the provider [10]. However, in the non-traumatic emergency setting, there are very few validated PoCUS protocols and no professional society consensus exists, to guide the clinician (anesthesiologist, intensivist, surgeon, or emergency physician) in the evidence-based application of this technology [11, 12]. Nevertheless, the early recognition and correction of the physiological derangement are strongly recommended as a crucial aspect, especially in the urgent surgery setting, in improving the outcomes [8]. The decrease in the costs associated with PoCUS and its minimal invasivity, the technological improvements with reduced costs, and the rapidity of the clinical answers given at the bedside are the reasons behind the spread in the use of PoCUS by multiple specialists. Moreover, PoCUS is a validated tool to guide invasive procedures, e.g., vascular catheterizations, quite often performed before or during urgent surgery. In this chapter, all the clinical applications of PoCUS in the preoperative evaluation of the high-risk surgical patient will be reviewed. The reader should keep in mind that this is a cutting-edge application of relatively new technology, and there is still a lack of randomized controlled trials to fully support its role in perioperative care.

As demonstrated by several studies, a care bundle for patients undergoing emergency laparotomy significantly reduced the mortality, where it was adopted [13, 14]. Early assessment and resuscitation, prompt diagnosis, and goal-directed therapy are all components of the bundle, where a protocolized PoCUS approach could play a role.

Besides these components, the other components of the preoperative evaluation that could be managed with PoCUS are [11]:

- examination of gastric content
- identification/management of the difficult airway
- assessment for causes of respiratory distress
- cardiovascular/shock assessment
- abdominal evaluation

25.2 The Clinical Evaluation by PoCUS

As part of the evaluation of the surgical patient with high surgical risk, the PoCUS can be understood as a tool that is able to give an idea of the operational margin available to reduce risks and optimize the residual functional reserve. In this chapter, the reader will be guided through all these applications of PoCUS in the preoperative management of urgent non-cardiac surgery.

Since the early 90s, Lichtenstein and Axler described the use of PoCUS in intensive care patients as an instrument of rapid but comprehensive "whole body" evaluation [15]. In addition, in recent years, key opinion leaders have suggested and taught a "whole body" approach to PoCUS in the acute care setting, as a combination of cardiac, thoracic, vascular, and abdominal evaluation [16]. The authors of this chapter aim is to shift the focus in the use of PoCUS from the intensive care setting to the preoperative evaluation of the high-risk surgical patient requiring urgent surgery. The latter share some of the aspects with intensive care medicine (e.g., the airway management or the early hemodynamic assessment), but the overlap is not complete and the therapeutic goals can be different in the two settings. The ambition that stands behind this chapter is to provide an approach to the "whole body" PoCUS that would not be confined in the well-established bounds of intensive care medicine. There are, in fact, suggestions that wider use of PoCUS to medical specialties other than emergency and critical care medicine improve the quality and accuracy of the clinical management, whereas still strong evidence is needed [17–19]. Within this context, this chapter is not targeted to a specific specialty, and contains elements that could be of use by anesthesiologists, surgeons, emergency physicians, and intensivists. In this regard, it is important to underline that the level of detail of the individual "items" that will be illustrated in the chapter will necessarily be synthetic and as little specialized as possible. This approach certainly suffers from incompleteness, but it also has the merit of enhancing the multidisciplinary nature of PoCUS [20].

To provide a common thread to present all the elements of this evaluation, the authors of this chapter propose a scheme based on a clinical loop based on the sequence of physiological derangement, optimization, and ultrasound monitoring, as illustrated in Fig. 25.1. This approach was chosen, because it cannot be recognized as an anatomical or temporal starting point in the loop, nor an end. It is a continuous evaluation of the different items involved, starting from the anatomical region of interest, depending on the clinician's skills and the characteristics of the clinical scenario. It is to be noted that this is not a validated clinical protocol, but a simple guide in the hands of the clinicians to summarize the key elements in the PoCUS that can be of use in the evaluation of the high-

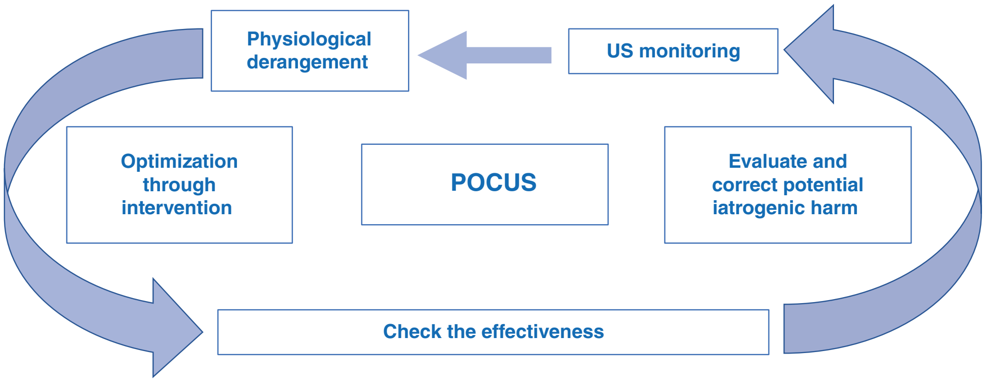

Fig. 25.1 Clinical loop of PoCUS in the evaluation of the high-risk patient undergoing urgent surgery

risk surgical patient requiring urgent non-cardiac surgery, based on the principles of the evidence-based medicine.

A "whole body" approach for perioperative management has been proposed by Ramsingh and colleagues [21]. This approach has been retrospectively compared with a traditional assessment in the perioperative evaluation of all kinds of surgical patients, demonstrating a statistically significant higher accuracy in new diagnosis examinations (OR estimate 0.01613, 0.00–0.079). In this study, the PoCUS impacted clinical perioperative management in at least 50% of the patients, with a 30% rate of new diagnosis [22].

The association of ultrasound diagnosis in perioperative decision-making is summarized in a recent meta-analysis by Ferreira Albuquerque Costa. Airways assessment, gastric, lung, and transthoracic ultrasound all-together accounted for 84% of the perioperative scanning techniques evaluated. The impact of ultrasound in therapeutic management and decision-making resulted in a risk difference of 0.169 (95% CI 0.1–0.24), with a low probability of bias. However, as already expressed above, the evidence base is still confined to uncontrolled observational studies, and more randomized controlled trials would be needed to support these findings [23]. It is reasonable to think that these data, when applied to the context of time-dependency, could show the best performance of PoCUS in terms of impact on the clinical decision-making process. POCUS must be considered as a clinical decision-making tool capable not only of providing diagnostic indications, and of allowing some invasive procedures, but also of integrating these characteristics in a clinical loop of diagnosis–action–evaluation of the effects, in an iterative process. Clinical examples will be provided through the chapter with pragmatic applications of the clinical loop described above (Fig. 25.1) to the "real world".

25.3 Gastric Content

Emergency surgery is a well-known risk factor for anesthesia-associated aspiration of gastric content [24]. The patient management regarding the risk for aspiration is generally

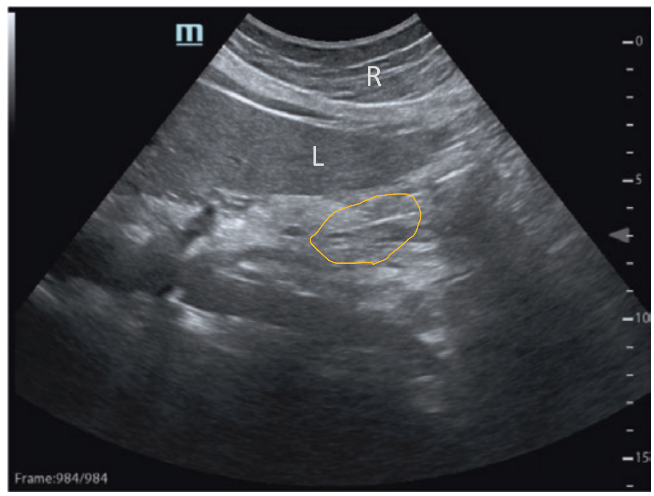

Fig. 25.2 Sagittal plane of the epigastrium showing the empty gastric antrum (surrounded by yellow line); L = liver, R = rectus abdominis muscle

based on the feeding history. The lack of an objective bedside assessment, especially in the cases where the history can be difficult to obtain or unreliable, e.g., poor consciousness, is making PoCUS and emerging technique in order to get information regarding gastric volume and content [25]. The meaning of PoCUS in this context is to provide an individual risk stratification tool and optimize the management to prevent unexpected aspiration of gastric content [26].

The examination should start with the individuation of the relevant anatomic structures on the patient in the supine and right lateral decubitus (RLD) position with a curved-array, low-frequency transducer. If the RLD position is not feasible, e.g., trauma patients, an acceptable alternative is the 30° head-up supine position [27].

If the stomach is empty, the antrum can be spotted as a flat, collapsed structure just below the rectus muscle (Figs. 25.2 and 25.3). An empty stomach is associated with a low risk of aspiration during anesthesia [28]. If the stomach contains clear fluids or gastric secretions, they can be seen as hypoechoic or anechoic contents, with distension of the muscular structures composing gastric walls. In the early phase

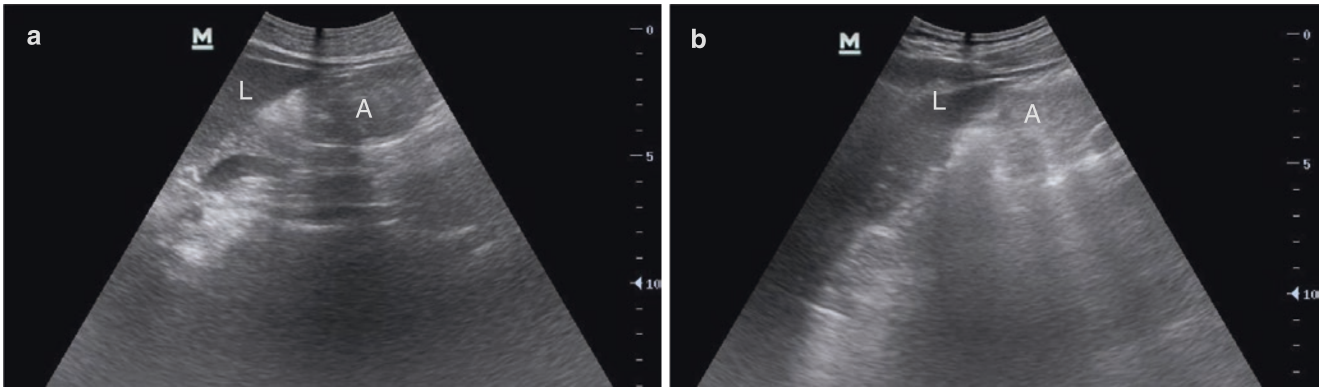

Fig. 25.3 (**a**) Sagittal epigatsric scan of a stomach filled by hypoechogenic fluid (water). (**b**) Same scan of the gastric antrum after the ingestion of solid content, generating the typical «starry night» image of the air bubbles trapped into the hypoechoic substance; L = liver, A = antrum

after solid ingestion, the swallowing of air bubbles creates a "frosted glass" image because of the interaction between the air and the gastric walls. As soon as the air disappears, the solid content in the stomach is visualized as a hyperechoic heterogeneous substance dilating the antrum.

Then, the cross-sectional area (CSA) of the antrum should be measured, using the specific trace tool. The most robust and validated statistical model that correlates the antral RLD (right lateral decubitus) CSA and gastric volume with high intra- and inter-rater reliability is calculated as it follows [28–30]:

$$\text{Gastric volume}(\text{mL}) = 27 + (14.6 \times \text{RLD} - \text{CSA}) - (1.28 \times \text{age}[\text{years}])$$

According to the algorithm reviewed by Van De Putte and colleagues, the aspiration risk is low in the case of an empty stomach, and high when solid material is detected. On the contrary, in a situation of clear fluid, the value of 1.5 mL/kg of gastric volume is used as a cutoff to discriminate between patients needing a change in the management of the airway because of an increased risk for aspiration [31]. It is important to underline that the previous model is validated on non-pregnant adult patients, and further studies are required to extend its validity to other populations.

25.4 Identification/Management of the Difficult Airway

After the assessment and eventual prevention of the aspiration risk, the early recognition of potential difficulties in the management of the airways constitutes the main goal in the care of the acute patient undergoing urgent surgery. The sonographic evaluation of the airways may be performed before securing them, but also as a tool for orienting and monitoring the whole procedure.

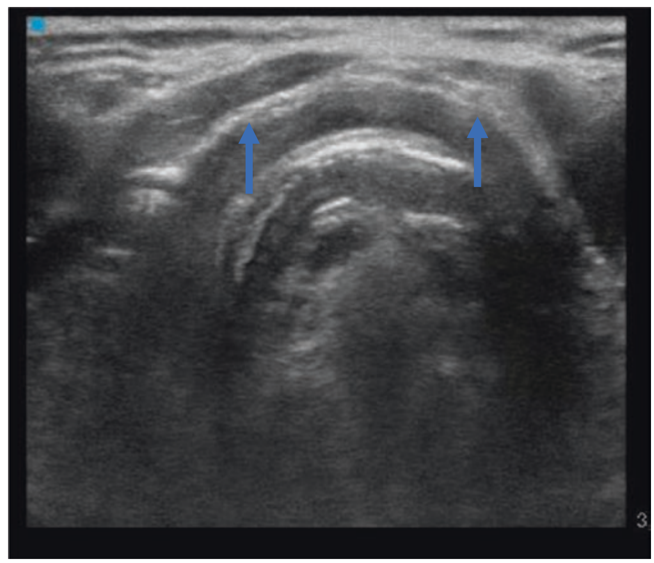

Fig. 25.4 Transverse scan of the anterior part of the neck. It allows the visualitation of the tracheal rings (blue lines), allowing also the precise quantification of their distance from the skin level

With a high-frequency linear probe, it is possible to obtain, rapidly and accurately, the exact position of the patient's trachea and to evaluate any deviations from the neck midline [32]. Starting from the thyroid cartilage and moving distally, with the probe in the transversal position, it is possible to recognize the exact position of the tracheal lumen with respect to the midline of the neck (Fig. 25.4). Any deviation from the midline, e.g., a hematoma of the neck displacing the trachea on one side, it is associated with an increased risk of difficult intubation. Rotating the US probe 90° clockwise, a longitudinal scan of the trachea is visualized, and in about 10 s, the cricothyroid cartilage can be identified (Fig. 25.5). The capacity to provide a clear image of the upper airways anatomy also in complex situations, such as with obese patients or burn victims, can be useful especially in urgent scenarios, for example, in the anticipation and/or planning of a cricothyrotomy or tracheotomy [33–35].

Probably the most helpful validated use of PoCuS in the management of the airway of the urgent surgical patient is represented by the possibility to check the proper position of the endotracheal tube (ETT) after the intubation maneuver [36]. The TRUE technique (tracheal rapid ultrasound exam) was implemented to confirm the position of the ETT, basically excluding its placement in the esophagus. Despite a good visualization of the trachea, it is not always possible to clearly distinguish the presence of the ETT from the lumen itself. The presence of a round-shaped, hyperechoic (white) artifact, with a black shadow beneath what normally is recognized as the esophagus, indicates the presence of the ETT in the wrong virtual lumen (Fig. 25.6). Therefore, the correct position of the ETT in the trachea is confirmed by its absence in the esophagus. The TRUE technique was found to have a pooled sensitivity of 98.9% and specificity of 94.1% in the confirmation of proper tracheal intubation, with a median operating time of 9 s [37–39]. In addition, the recognition of a normal bilateral pleural sliding indicates physiological ventilation of both lungs, which is a strong indication of the right placement of the ETT. In this regard, the pulmonary tree and lung expansion ultrasound study protocol has been demonstrated to be superior against auscultation in identifying tracheal vs. bronchial intubation, as recently published by Ramsingh and colleagues [40].

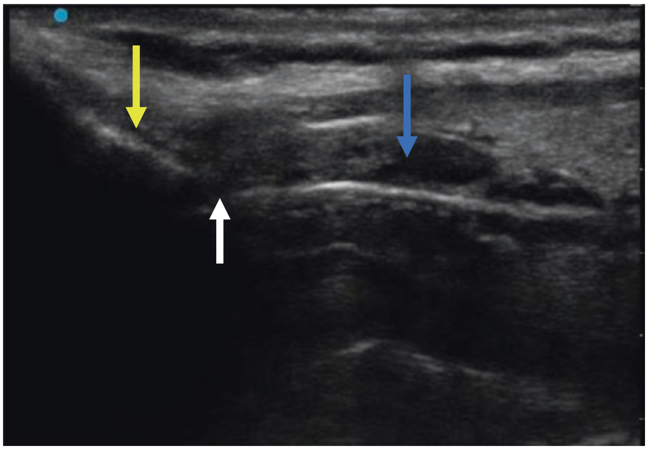

Fig. 25.5 Longitudinal scan of the trachea. It allows the precise detection of the cricoid cartilage (blue arrow). The thyroid cartilage is indicated by the yellow arrow, as well as the median cricothyroid ligament (white arrow)

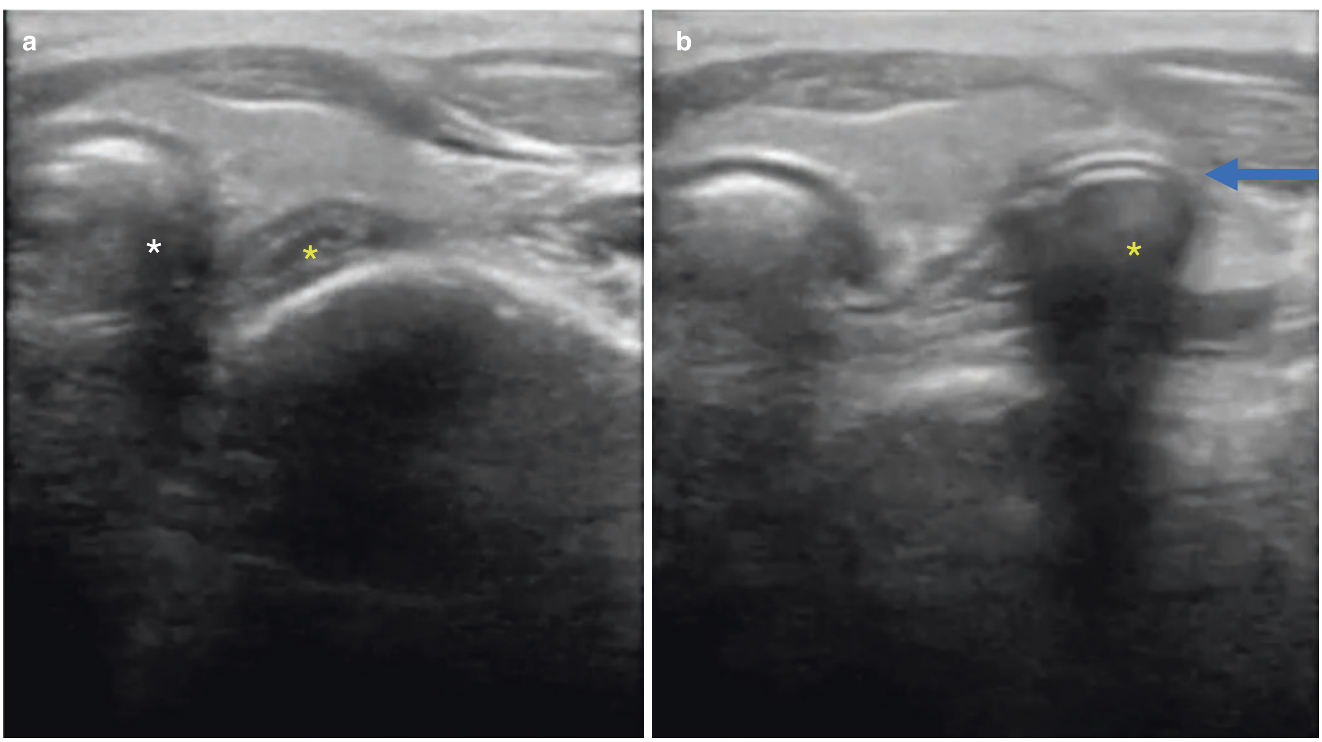

Fig. 25.6 (**a**) Left transverse anterolateral scan of the neck. The anatomical relations between the trachea (white asterisk) and esophagus (yellow asterisk) are shown. (**b**) Using the same scan as in (**a**), it is possible to visualize the trachea (white asterisk) and the tram track hyperechoic profile of the endotracheal tube (blue arrow) incorrectly placed in the esophagus (esophageal intubation). The yellow asterisk shows the posterior shadowing generated by the tube

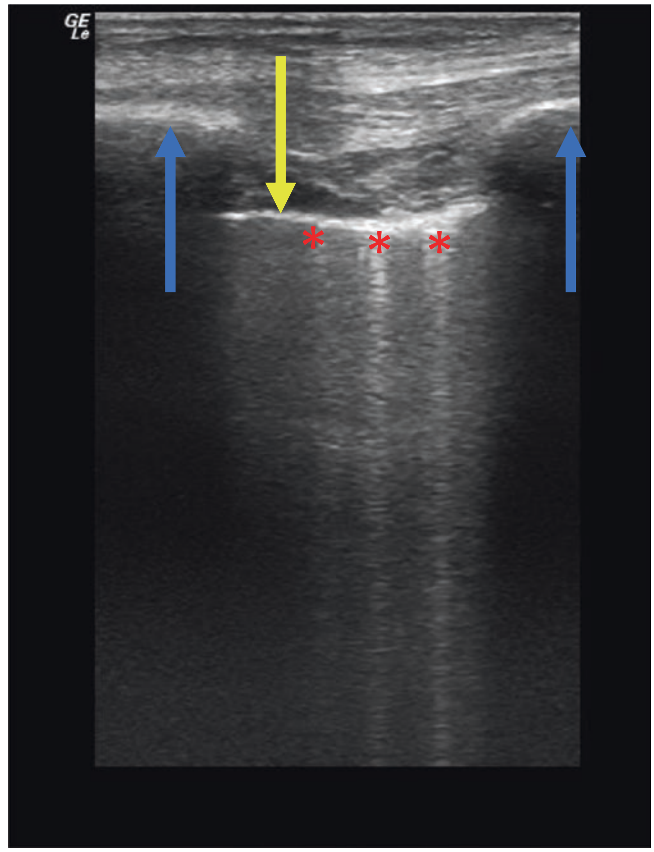

Fig. 25.7 «bat sign», obtained by a longitudinal scan of the thorax with a linear probe. The shadow cones generated by two contiguous ribs are marked with the blue lines. Three isolated B-lines are visualized (asterisk) starting from the pleural line (yellow arrow)

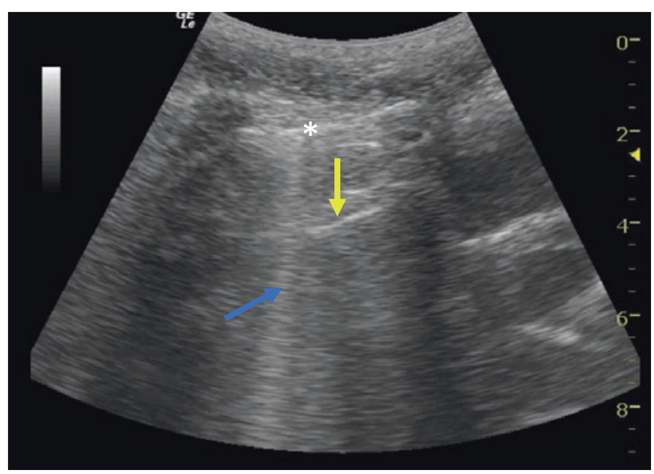

Fig. 25.8 Longitudinal scan of the thorax, showing the lung point (white asterisk, see the text for a complete explanation). The B lines (blue arrow) are a direct sign that the two pleural layers are attached. On the contrary the A lines (yellow arrow) are not generated but reinforced by the air caused by the pleural layers detachment (pneumothorax)

25.5 Assessment for Causes of Respiratory Distress

After its introduction in the early 90s, the use of lung ultrasound in the care of critically ill patients has dramatically increased, becoming the standard of care through the last decade [41, 42]. The spread in its use across critical care and emergency medicine physicians worldwide, especially during the COVID-19 pandemic [43], has increased the interest in this technique also in different settings. Lung ultrasound is based on the interpretation of the artifacts created by the interaction between air and ultrasound wave propagation. These artifacts can be classified as horizontal or vertical ones, with different meanings about the pathological process (or its absence) that created them. All the artifacts originate from the pleural line, which is defined by a hyperechoic (white) line that moves horizontally with every breathing act (lung sliding). The standard scan in lung ultrasound is represented by the well-known bat sign image. This image can be obtained with a longitudinal scan of the thorax, in which the pleural line is surrounded by two anechoic (black) shadow cones, generated by two consecutive ribs that stop and totally reflect the ultrasound wave. Once visualized the standard scan, either horizontal or vertical artifacts appear from the sliding pleural line. The “A lines” are hyperechoic horizontal linear artifacts that appear in a repetitive pattern under the pleural line, meaning normal lung parenchyma. On the contrary, the “B lines” are vertical hyperechoic artifacts that several authors described as comet tails (Fig. 25.7). These artifacts are generated from the interaction between two media with different acoustic impedances, namely, air and water, in the situation of a wet lung (e.g., pulmonary edema).

The main use of lung ultrasound in the context of the high-risk patient is linked to the BLUE protocol, in case of acute respiratory failure. Following the algorithm all the principal causes of respiratory insufficiency can be excluded, with an accuracy superior to 90% [44]. The presence of B-lines is more sensitive than chest X-rays in detecting pulmonary edema, and can rapidly orientate toward different managements of the patient [45]. Another useful application of lung ultrasound in the preoperative evaluation is the possibility to rule in or rule out (in a few seconds) pneumothorax. The presence of B-lines and/or pleural sliding allows the exclusion of pneumothorax in the differential diagnoses. The rule in the sign of pneumothorax instead is called lung point. The lung point is defined as the exact point in which the detached visceral pleura, during inspiration, touches the parietal pleura again (Fig. 25.8). The specificity of lung point is about 100% [46].

Finally, lung ultrasound is recognized as a powerful tool for the fast detection of parenchymal consolidations, such as pneumonia or atelectasis [47]. In this case, the area involved can be spotted as a relatively hypoechoic echotexture, with inside hyperechoic inclusions (lines or dots) which represent the air bronchogram [48]. If the air bronchogram appears as modified by the respiratory movements is called dynamic,

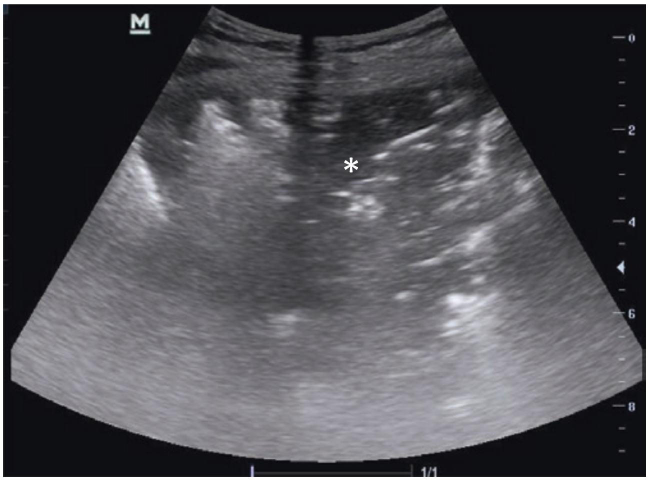

Fig. 25.9 Longitudinal scan of the thorax at the midaxillary line obtained by a convex probe, showing an extensive lung consolidation (white asterisk). Note the tissue-like echographic appereance of the consolidation with its irregular inferior profile (shred sign). The hyperechoic white inclusions in the lung parenchima represent the air bronchogram

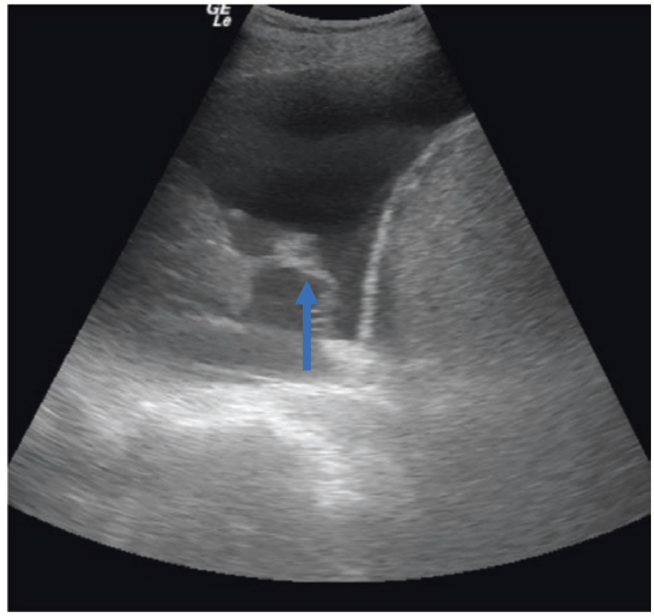

Fig. 25.10 Longitudinal scan of the thorax at the midaxillary line obtained by a convex probe, showing an extensive hypoechogenic pleural effusion next to an area of pulmonary consolidation. The blue arrow point out a fibrin strand attached to the lung and diaphragm

and it is strongly predictive of pneumonia (Fig. 25.9). On the contrary, a static bronchogram is suggestive of atelectasis. Moreover, in the case of atelectasis, the tree-like arrangement of the bronchi is changed to a parallel pattern (because the parenchyma makes them parallel by compressing itself). Finally, through lung ultrasound the presence of pleural effusion can be easily diagnosed and measured, as hypoechogenic fluid between the parenchyma and the surrounding structures (e.g., the diaphragm or the chest wall) (Fig. 25.10).

When applied to a population of patients undergoing elective cardiothoracic surgery, lung ultrasound detected the presence of any pathology in 56% of the cohort, with high a estimate of interobserver agreement beyond that expected by chance [49].

At the moment, there are no solid evidence in the literature supporting the use of lung ultrasound in the preoperative evaluation of the acute patient [9], but PoCUS and lung ultrasound are becoming part of the anesthesiologists standard skills [50]. In the recent review by Meier et al., the diagnostic value of lung ultrasound in the preoperative clinic is rated low for most of the patients, whereas it could be used as a supporting tool to rule in or rule out suspected cardiac failure [9]. More research is needed on this topic, but the authors of this chapter believe that in a context of time dependency, the value of lung ultrasound is probably more than in the elective context. In this regard, in the study by Zieleskiewitcz and co-workers, lung ultrasound was able to predict an increase in cardiac filling pressures with a positive predictive value of 0.57 (95% CI 0.28–0.82) and a negative predictive value of 1.00 (95% CI 0.87–1.00) in parturients with severe preeclampsia [51]. Moreover, lung ultrasound, meaning in the context of the high-risk surgical population, is not limited to the preoperative evaluation, but can be used as a monitoring tool in the post-operative phase.

As mentioned in the introductory chapter, lung ultrasound on acute surgical patients can be considered as a tool capable of generating a clinical loop of diagnosis, treatment, and feedback. For example, in the typical case of a hypoxic postoperative patient, through the use of pulmonary ultrasound, it is possible, as we have seen, to diagnose pulmonary atelectasis. Management optimization through high PEEP ventilation and recruitment maneuvers can be guided bedside through serial repetition of the POCUS bedside through a feedback approach.

25.6 Cardiovascular Assessment

Bedside cardiac ultrasound (BCU) is recognized as an important tool in the evaluation of critical patient. According to the "Guidelines for the Appropriate Use of Bedside General and Cardiac Ultrasonography in the Evaluation of Critically Ill Patients", the most robust recommendations include the use of BCU for the assessment of fluid responsiveness in the mechanically ventilated patient and for the detection of pericardial tamponade [52].

In the setting of a patient undergoing urgent surgery, the BCU needs to be oriented first to fluid resuscitation management. Moreover, BCU is a powerful tool for a comprehensive differential diagnosis of the many causes of pulseless electrical activity or shock. It enables, in fact, the physician to diagnose the likely cause of hemodynamic instability, such as hypovolemia, cardiac failure, or pericardial effusion in a few minutes, even during cardiopulmonary resuscitation.

Cardiac ultrasound should be performed using a low frequency (3.5–5 MHz), generally phased array probe. The first step in the cardiac evaluation of the critical patient undergoing urgent surgery is the inferior vena cava (IVC) diameter measurement and its relative modifications induced by the respiratory movements. For the IVC detection, the standard approach is obtained by placing the probe in the subxiphoid area, with the marker pointing toward the right of the patient. Once visualized the heart, the probe needs to be rotated 90° upward until the IVC is longitudinally scanned in its terminal portion, about 2 cm before it enters the right atrium (Figs. 25.11 and 25.12). The IVC diameter modifications are dependent on the pressures exerted on the thorax by the respiratory dynamics. In the spontaneously breathing patient, the negative pressures generated by the respiratory muscles are responsible for a reduction in the IVC diameter (collapse). On the contrary, in the mechanically ventilated patient, the increase in positive pressure during the inspiratory phase is responsible for an increase in IVC diameter (distension). In both cases, the variations induced by the respiratory pattern tend to decrease with all the conditions associated with fluid non-responsiveness. Any change in the IVC diameter between inspiration and expiration (Δ IVC) superior to 50% in spontaneously breathing and to 18% in mechanically ventilated patients should be considered suggestive for fluid responsiveness. Evidence suggests that Δ IVC measured with POCUS could be predictive of fluid responsiveness [53]. However, a recent meta-analysis showed an extreme heterogeneity in the studies included, and the role of POCUS seems to be an element that needs to be integrated with other hemodynamic monitoring methods [54]. It is to be noted that this approach needs to be more cautious in the non-invasively ventilated patients. In fact, the sitting position and the non-predictable changes in pleural pressures during non-invasive ventilation make Δ IVC cutoffs less predictive of fluid responsiveness. The preoperative IVC collapsibility, however, has been found to be predictive of hypotension after induction of general anesthesia by Zhang and co-workers [55].

As explained in the paragraph regarding the lung ultrasound, the suspect of cardiac origin in a situation of shock or low perfusion can be reinforced by the presence of “B lines”. The rapid assessment of the cardiac chambers, abnormal motion of the walls, and the finding of significant valvular disease could all increase in a timely manner the pre-test probabilities of cardiac disease and address the request for a specialist consult.

The focus-assessed transthoracic echocardiography (FATE) and Rapid Ultrasound in SHock (RUSH) protocol

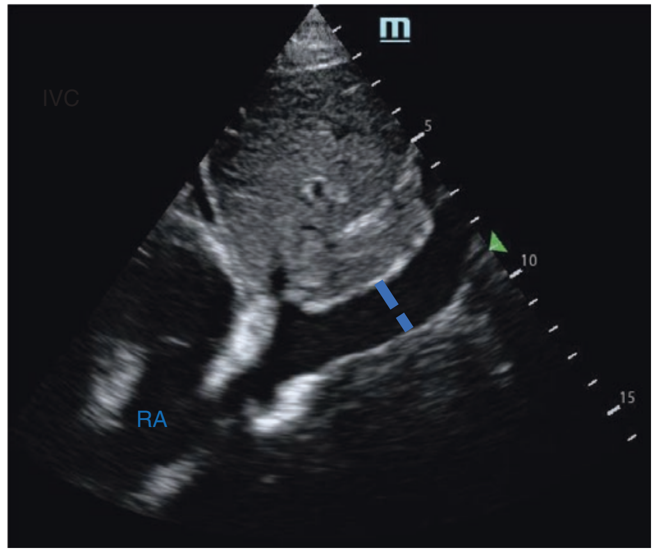

Fig. 25.11 Longitudinal scan of the inferior vena cava, performed by a low-frequency, phased array probe. To properly localize the IVC and differentiate it from the aorta, its entrance into the right atrium (RA) needs to be visualized. The dotted line represents the point, where the IVC diameter should be correctly measured

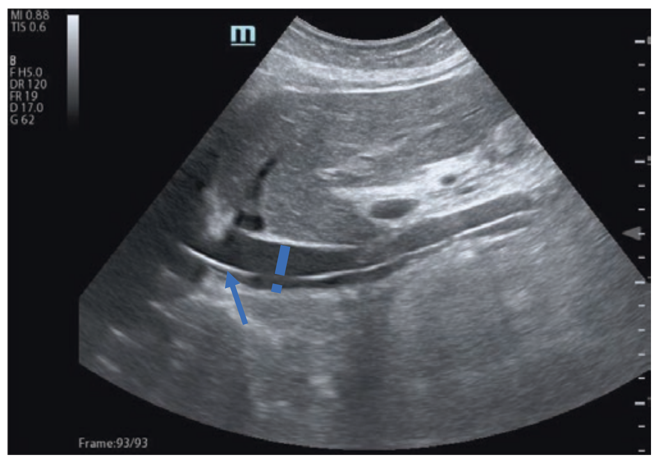

Fig. 25.12 Longitudinal scan of the inferior vena cava entering the right atrium, performed by a convex probe. The presence of a temporary pacemaker catether is indicated by a blue arrow. The dotted line represents the point, where the IVC diameter should be correctly measured

have been designed to rapidly address these issues in critically-ill patients [56], but they can also be applied to a surgical population [57, 58]. In about 70 s, a trained physician can evaluate the genesis of cardiovascular instability and plan for any change in the perioperative management, as well as serially monitor the hemodynamics [59]. The basic scanning positions of the FATE protocol are four (subcostal, apical, parasternal, and pleural). They allow detecting obvious pathology potentially affecting hemodynamics, assess wall thickness and biventricular function, globally evaluating heart function in the clinical context. For performing the

RUSH protocol, the authors recommend the use of a phased array transducer (3.5–5 MHz) for the thoracoabdominal scanning and a linear array transducer (7.5–10 MHz) for the venous examination and for the detection of an eventual pneumothorax. The RUSH protocol is a physiological assessment of a patient in shock, and can be simplified in the three steps of pump, tank, and pipes [56]. The cardiac status is investigated through four views of the heart (long and short axis, subxiphoid, and apical), which constitute the evaluation of the "pump". The "pump" step is directed to the detection of an eventual pericardial effusion, to estimate the global contractility and to determine the relative size of the right ventricle to left ventricle (Fig. 25.13). The second part of the RUSH protocols focuses on the evaluation of the volume status, which is referred to as the "tank". The "tank" evaluation starts from the IVC diameter modifications and continues with the search for any pathologic abnormality responsible for a "leakiness" in the vascular system (abdominal or thoracic hemorrhage) or a compromise of the vascular volume by pneumothorax (Fig. 25.14). The third component of the RUSH is targeted to the evaluation of the large arteries and veins of the body, or "pipes", in search for any rupture or obstruction as a plausible cause of shock [56]. A complete description of the FATE and RUSH protocols can be found in dedicated apps and online resources. In the same way, it is not possible for the authors to provide a comprehensive illustration of all the technical details of a complete BCU examination that can be found in specialized textbooks and certified courses by the main scientific societies involved in PoCUS.

In the interesting study by Andruszkiewicz et al., the use of BCU by the primary-treating physician in the preoperative evaluation has been demonstrated comparable with a cardiology consultation. After brief training in cardiac ultrasound and following a simplified scheme, the agreement between anesthesiologists and cardiologists has been found to be 97.8% of the examined categories, leading to a change in the preliminary anesthetic plan in relation to 20.8% of the patients [60].

In the systematic review, Heiberg and colleagues analyzed the impact of focused echocardiography on clinical decision-making in anesthesia and critical care. Despite the well-known lack of high-quality evidence, 13 out of 18 prospective studies were supportive of the focused echocardiography bedside. In this study, the impact of BCU on the preoperative evaluation ranged from 17% to 78% regarding a change in diagnosis and from 12% to 82% regarding a change in the perioperative management [61]. It is interesting to underline that in this systematic review, the majority of the studies in the anesthetic setting were performed on a population of patients undergoing emergency surgery [62–65].

In a recent paper by Kratz et al., the focused transthoracic echocardiography was used perioperatively for hemodynamically unstable patients undergoing high-risk non-cardiac surgery. In 66% of the patients, the transthoracic echocardiography led to a change in the perioperative management, such as a change in fluid or drug therapy. The most frequent reason for a change in the management was hypovolemia, but also aortic stenosis, left ventricular dysfunction, and right heart failure were detected and treated [66].

In addition, in this case, it is possible to give an example of a clinical loop, recalling the introduction. For example, it is possible to imagine a patient categorized as fluid responsive with the contribution of the evaluation of the IVC (integrating all available clinical data). The following volume resuscitation phase can be monitored in real time with the

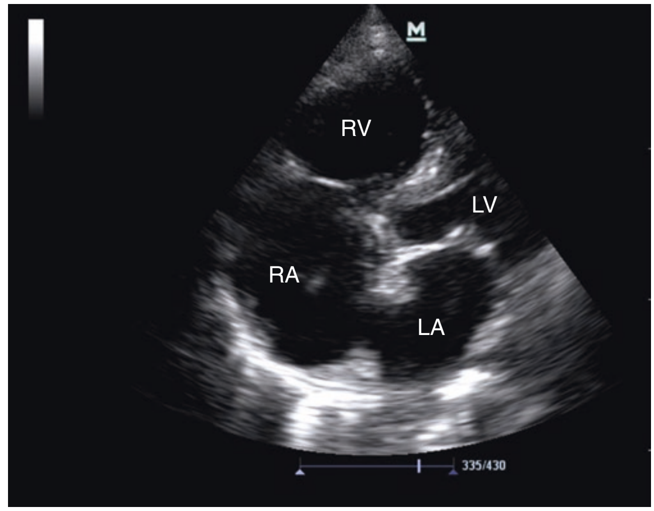

Fig. 25.13 Four chamber view of the heart, obtained with a low-frequency, phased array probe. The right side of the heart is visibly dilated. *RV* Right ventricle, *LV* Left ventricle, *RA* Right atrium, *LA* Left atrium

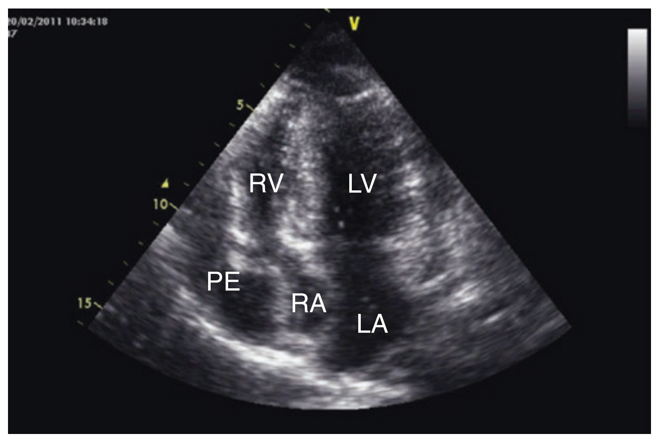

Fig. 25.14 Four chamber view of the heart, obtained with a low-frequency, phased array probe. A massive pericardial effusion can be detected, compressing the heart and producing the collapse of the right side of the heart. *RV* Right ventricle, *LV* Left ventricle, *RA* Right atrium, *LA* Left atrium, *PE* Pericardial effusion

use of lung ultrasound that can identify by the appearance of posterior–inferior B lines growing in an anti-gravity fashion, a typical sign of initial overload. In this clinical scenario, it is interesting to recall the whole-body approach described above (Fig. 25.1). Through the movement of the probe on different anatomical districts, it is, therefore, possible to monitor changes in the pathophysiology, check the efficacy of the interventions, and obtain signs of an eventual iatrogenic arm.

25.7 Abdominal Evaluation

The main evidence about the use of abdominal PoCUS as a screening tool in the acute care setting is basically limited to trauma patients [67, 68]. However, many surgical societies (e.g., the American College of Surgeons) recognize the value of PoCUS in the surgical evaluation and are implementing rigorous certifications of proficiency in the ultrasound techniques for trainees [69]. Recent literature in fact suggests that the empowering of the surgeon provided by the PoCUS can expedite diagnosis and provide rapid decision-making in trauma and emergency surgery [12]. Nevertheless, more research is needed to overcome the barriers represented by the scarce availability of randomized controlled trials and the inhomogeneity of educational programs among clinicians worldwide [70]. In the *Guidelines for the Appropriate Use of Bedside General Ultrasonography in the Evaluation of Critically Ill Patients*, the use of abdominal PoCUS is recommended as guidance to determine the optimal location for performance of paracentesis in non-traumatic ascites [71].

After its introduction in the last decade of the twentieth century, the Focused Assessment with Sonography for Trauma (FAST) is now a key component of trauma management algorithms [72, 73]. The FAST protocol, and its extension E-FAST (which includes pneumothorax assessment), is currently required by the major certifications in trauma care.

The FAST exam is generally performed with a curvilinear low-frequency (3.5–5 MHz) transducer. The basic views are four: right flank, left flank, suprapubic, and subxiphoid. The liver is used as an acoustic window to localize the hepatorenal space and liver parenchyma. In the left flank view, the splenorenal fossa is scanned. The suprapubic view allows detecting eventual free fluid in the pouch of Douglas, especially in the presence of a distended bladder, supplying an ideal acoustic window. The subxiphoid view is dedicated to the study of the pericardium. Broadly speaking, hemoperitoneum (or pericardial effusion) appears as anechoic or hypoechoic fluid surrounding the solid organs [74]. The entire FAST scanning could take 2–5 min, making it ideal in the rapid evaluation bedside in an emergency scenario (Fig. 25.15).

In the Cochrane systematic review by Stengel et al., the sensitivity and specificity of abdominal point of care ultrasonography in blunt trauma have been calculated, respectively, in 0.74 (95% CI 0.65–0.81) and 0.96 (95% CI 0.94–0.98). Therefore, a negative PoCUS exam in the context of abdominal trauma does not rule out injuries, and the patient could need a reference test, such as a computed tomography (CT) scan [67]. On the contrary, a positive FAST exam in a hypotensive patient after a blunt abdominal trauma may warrant a surgical laparotomy [75].

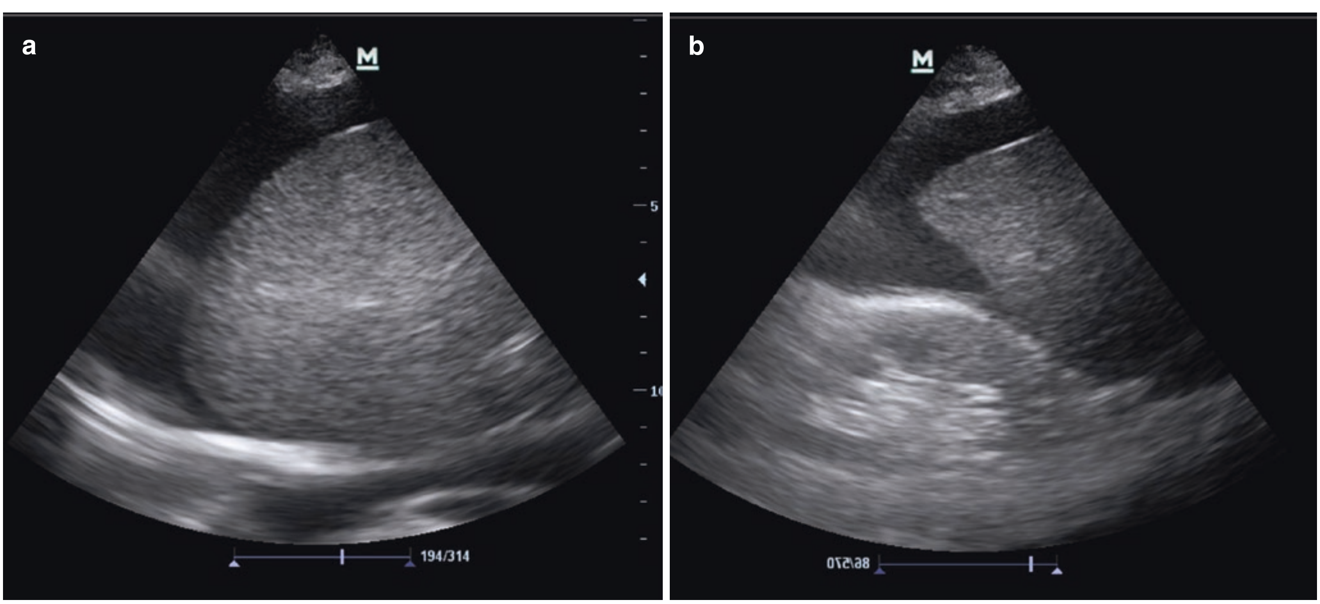

Fig. 25.15 (**a**) Right upper quadrant abdominal scan showing subdiaphragmatic/periepatic fluid (anechoic). (**b**) Fluid is also detectable in the Morrison's pouch

Several authors have also explored the utility of abdominal ultrasound in the evaluation of the acute abdomen also in the non-traumatic setting. Although CT represents the modality of choice for the evaluation of the acute abdomen, the role of PoCUS abdominal ultrasound still plays an important role in the diagnostic management of this condition. The wide availability of ultrasounds in the emergency departments and critical care units, and the need for a limitation of the radiological exposure, makes PoCUS a primary imaging technique [76].

In a population of emergency department patients complaining of non-traumatic abdominal pain, the use of ultrasound led to a change in the treatment plan for 47% (95% CI 41.3–52.6%) of the patients [77]. Interestingly, in this study, most of the patients, who might have been treated surgically according to the initial clinical impression, were treated medically after the ultrasound screening by the radiologist. In this regard, the ultrasound abdominal screening provides a tool able to prevent unnecessary surgeries in patients who have acute abdominal pain, or to direct to further investigation the patients who need it, in a timely manner and bedside.

In a pilot observational study, Jang and co-workers suggest that PoCUS abdominal ultrasound performed by emergency physicians could improve the decision-making process and the diagnostic workup of the patients presenting with non-specific abdominal pain [78]. In another study, 800 patients who were attending the emergency department for abdominal pain were randomized to undergo or not undergo PoCUS performed by a trained surgeon. The diagnostic accuracy was significantly higher in ultrasound group compared to the standard of care (64.7% vs. 56.8%, $p = 0.027$) [79]. The main applications of abdominal PoCUS in the non-traumatic setting include biliary, urinary tract, abdominal aortic aneurysm, and intrauterine pregnancy [80].

25.8 Conclusions

Along with this chapter, the reader has been guided through the key items of PoCUS in the evaluation of the high-risk surgical patient requiring urgent non-cardiac surgery. As explained above, the authors do not aim for an exhaustive explanation of the technical details of the single items. On the contrary, a wider approach would be suggested for a book chapter, with the goal of giving a general overview of the latest evidence in the clinical application of a relatively new tool. Moreover, several topics have not been treated as, for instance, the use of PoCUS as procedural guidance for maneuvers, such as central venous catheters placement, paracentesis, pericardiocentesis, or loco-regional anesthesia. The authors believe that all of them are too specific for a chapter targeted to the preoperative evaluation and refer to other manuals and articles for a complete description of those techniques.

It should be clear enough at this point that PoCUS in the context of preoperative evaluation is an evolving technique, subject to continuing technological improvements and new applications. Still, a lot of work needs to be done to strengthen the burden of evidence supporting PoCUS, especially through the execution of randomized controlled trials, still in insufficient number despite its wide implementation worldwide. This chapter should be, therefore, considered a starting point for the reader. All the main scientific societies in surgical sciences, emergency medicine, intensive care, and anesthesiology are promoting specific programs to standardize the ultrasound curriculum of residents in the field of PoCUS. The authors, therefore, refer the interested reader to those programs to promote certified knowledge in these and other applications of PoCUS.

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