

B-lines and beyond: Lung ultrasound for the perioperative clinician

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INTRODUCTION

Severe perioperative hypoxaemia, defined as a $SpO_2 \leq 85\%$ for two minutes or longer, is a relatively common event, occurring in 3.5% of patients in one study,¹ with potential significant harm to the patient. In order to narrow the differential diagnosis of hypoxaemia and target treatment, the perioperative physician often relies on clinical suspicion, examination and chest radiography (CXR). However, clinical examination, including lung auscultation^{2,3} and fluid status assessment,^{4,5,6} has high inter-operator variability. CXR has limitations, including the logistics, poor sensitivity to early changes, and inter-operator interpretation at the point of care.⁷ Finally, empirical management, such as increasing positive pressure ventilation or diuresis, may pose potential harm to patients.

Initially, lung ultrasound (LUS) was thought to be infeasible due to air in the lungs obstructing the passage of ultrasonic waves. However, in the 1990s, Dr Daniel A Lichtenstein uncovered multiple artefacts consistently associated with specific conditions, the interpretation of which forms the basis of LUS today. This led to the development of the original point-of-care LUS protocol: "Bedside Lung Ultrasound in Emergency (BLUE)".⁸

LUS utilises a rapid, easily accessible point-of-care tool to aid in perioperative decision-making. LUS can assist in the evaluation of pneumothorax, pneumonia, pulmonary oedema, atelectasis, and other common causes of severe perioperative hypoxaemia or any perioperative respiratory distress. Newer protocols, such as eFAST⁹ and RUSH,¹⁰ have been widely embraced in intensive care and emergency departments to approach ultrasound scanning systematically, with resultant high inter-operator agreement and reproducibility. Small studies show LUS changes physicians' management plans,^{11,12} reduces IV fluid administration, and improves mortality.¹³ However, LUS has experienced limited exposure in the perioperative environment due to a lack of formal training, variable expertise and operator dependence,¹⁴ inconsistent access to ultrasound machines, perceived limited utility, and operational constraints. Therefore, this article aims to familiarise clinicians with the basis of LUS physics, findings and interpretation, through a recommended protocol.

LUS VERSUS CONVENTIONAL RADIOGRAPHY: CHEST X-RAY (CXR) AND COMPUTED TOMOGRAPHY (CT)

All three imaging modalities (LUS, CT and CXR) provide valuable information regarding lung fields and pathologic conditions. LUS and CXR are both available as point-of-care modalities, eliminating the need for patient transport; the technologies are widely accessible, and images are retrieved easily. However, LUS and CT differ significantly. Table 1 highlights the advantages and disadvantages of LUS compared with the other modalities.

Table 1. Advantages and disadvantages of LUS compared with CXR and CT

Advantages	Disadvantages
Widely available – does not rely on radiographer availability after-hours.	Operator typically a medical practitioner, increasing cognitive and temporal load.
Inexpensive – existing ultrasound almost universally available in Australia and New Zealand due to other indications (echocardiography, vascular access, regional anaesthesia).	Training and experience required beyond already expected proficiencies with radiograph interpretation.
Avoids ionising radiation – no risk to staff, negligible clinical thermal risk to foetus. ¹⁵	Potentially wide degree of operator dependency. ^{16,17}
Reduces occupational health and safety risk in positioning obese patients for CXR or transfer for CT.	Limited by various obstructions to the probe and patient positioning, especially breast and cardiothoracic surgery, dressings, etc.
Reduces risk to patient stability caused by transfer to CT scanner (a less clinically controlled environment).	Longer scan duration versus CXR (8-12 minutes versus < 30 seconds).
Faster to start scanning versus CXR, and overall versus CT, by avoiding booking, transfer, potential wait, and scan duration.	Less accurate versus CT (the gold or reference standard in many comparative sensitivity and specificity studies).
More accurate versus CXR for pneumothorax sensitivity (79% vs 40%), ¹⁸ pleural effusions (80-100% vs 24-100%), ¹⁹ and earlier identification of pulmonary oedema.	70% maximal coverage of lung in ultrasound contributing to reduced sensitivity as cannot rule out pathology.

PHYSICS AND EXPLANATION OF ARTEFACTS

A solid understanding of the physics behind LUS artefacts is crucial for accurate interpretation and recognition of underlying pathology. The conversion of ultrasound beams into an image by the processor assumes that: (a) sound travels at a constant speed in a straight line, (b) sound reflects once per tissue interface, (c) the interface is perpendicular to the beam, (d) sound returns directly to the transducer, and (e) the beam's attenuation is uniform and linear. When this expected pathway is disrupted, artefacts appear on the image.

Ultrasound beams are reflected whenever two tissues of differing acoustic impedance abut each other, forming an interface. The pleural interface (pleura to air in the lung) and the lung parenchyma-air interface cause virtually all beams to be reflected, creating artefacts in imaging that are interpreted (in other words, the lung itself is not imaged). Abnormalities within the pleura, interstitium, or alveoli produce unique, reproducible artefacts,²⁰ the most common of which are reverberation artefacts.

Reverberation artefacts occur when an ultrasound pulse encounters two closely spaced, parallel reflective surfaces. Instead of returning immediately, the pulse becomes trapped between them, bouncing back and forth before eventually reaching the transducer in delayed intervals. This repeated reflection produces a characteristic reverberation artefact on the ultrasound image.

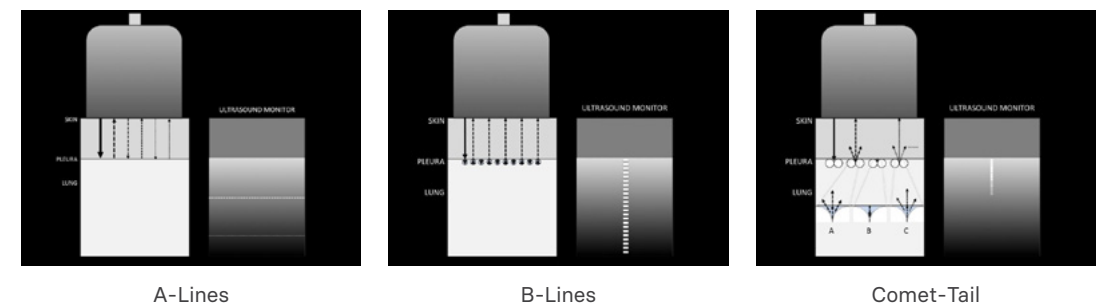
The different types of artefacts are described below and displayed in Figure 1.

A-lines are a form of long-path reverberation artefact. "Long-path" refers to a distance between the two reflective surfaces which is discernible to the human eye. Most of the ultrasound beam hits the highly reflective pleural surface, returning back to the probe – a true representation of where the pleura is located. However, some of the beam then continues to bounce between the probe and the pleura, forming subsequent horizontal lines or A-lines. They exhibit fade due to attenuation of the ultrasound beam with each reflection, diminishing with increasing depth.

B-lines are a form of short-path reverberation artefact, where the distance is less than half an ultrasound pulse length. The beam reaches a fluid-filled alveolus within secondary lobules, which are clusters of up to 30 acini, bound by interstitial fibrous septa. The beam bounces between the highly reflective superficial and deep fluid surfaces, and with each return, a small amount of pulse is sent back to the transducer. Due to the short distance, surface reflectiveness, and the fact that the surfaces are perpendicular to the beam, little to no attenuation occurs, and thus, B-lines do not fade.

Comet-tail artefacts are also short-path reverberation artefacts, but occur where ultrasound encounters highly reflective, closely spaced surfaces – such as calcium, cholesterol crystals, or metal – that are too small to be distinguished as separate structures. Unlike B-lines, comet-tail artefacts weaken with each reverberation, resulting in a bright, vertical streak that rapidly fades. This occurs because the beam either reflects off non-parallel reflective surfaces, causing scattering, or is absorbed by the tissues involved, both of which reduce the fraction of the beam that returns to the transducer. Confusingly, B-lines were previously called comet-tail artefacts, and even described as such in the BLUE protocol.

Figure 1. Graphical depictions of reverberation artefacts



Reproduced with kind permission from LITFL^{21,22,23}

PRACTICAL ASPECTS

Patient positioning

- Supine: most likely position intraoperatively. Ideally, arms out to improve access.
- Semi-recumbent: useful if patients are unable to lie flat, or there is a need to assess for an apical pneumothorax.
- Lateral and prone: useful for assessing a larger surface area of the lung.

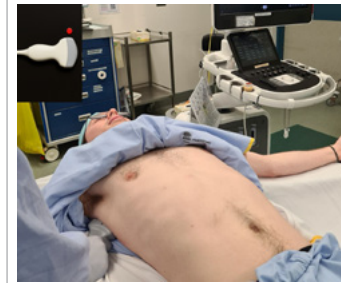
Probe selection and orientation

- Low frequency or curvilinear probe: all-purpose use.
- High frequency or linear probe: for interrogating the pleura.
- Phased array probe: particularly useful when performing concurrent echocardiography. However, the smaller footprint can challenge rib visualisation.
- The curvilinear probe is better than the phased array probe for interpretation, particularly for novices and pleural-based pathologies.²⁴
- Always scan in a longitudinal (rather than transverse) orientation, with convention dictating the left of the screen to be cephalad (head to left) – see Figures 2 and 3. This allows easy identification of the pleura between the two ribs.
- NB: The benefit of transverse orientation in regular scan is that more artefacts can be seen in a single respiratory cycle; however, this technique requires advanced operator skill and risks mistaking A-lines for the pleural surface.

Knobology

- Presets: use the “lung” preset if available. The “abdominal” preset is useful for assessing consolidation and effusions, but may diminish visualisation of A-lines, B-lines and pleural sliding. This is represented in Figure 4.
- Depth: set to 15–20 cm for lung imaging, but reduce depth for assessing pleura, or use the zoom function.
- Gain: adjust to maximise contrast and visualisation of the pleural line and B-lines (if present).
- Duration: scan each scanning zone for one respiratory cycle, or 5–6 seconds.
- Turn off focal zones: if you need one, position it at the pleural line.
 - Dial near and far field gain to the same brightness using time gain compensation (TGC); otherwise, the machine will dim distal B-lines.
- Advanced: turn off tissue harmonic imaging (THI) and spatial compounding – this will maximise artefacts generated.

Figure 2. Probe position over PLAPS point



Best achieved with the patient's arms out. Probe marker towards the head. PLAPS = posterior lateral alveolar and/or pleural syndrome

Figure 3. Longitudinal/parasagittal probe position, scanning over the anterior chest



Probe marker towards the head

Figure 4. Ultrasound with “MSK” preset used



Head to left. MSK preset used. THI off. A-lines demonstrated (SonoSite SII, FUJIFILM Sonosite, Inc. Bothell, WA, USA)

LUNG SIGNS: DEFINITIONS AND DESCRIPTIONS

We have attempted to collate the various nomenclature here to avoid confusion between contemporary and historical terminology; these are presented in Table 2. The term “profile” refers to a characteristic image acquired in the original BLUE protocol. Images representing many of the artefact lines that are utilised in scanning protocols are presented in Figure 5.

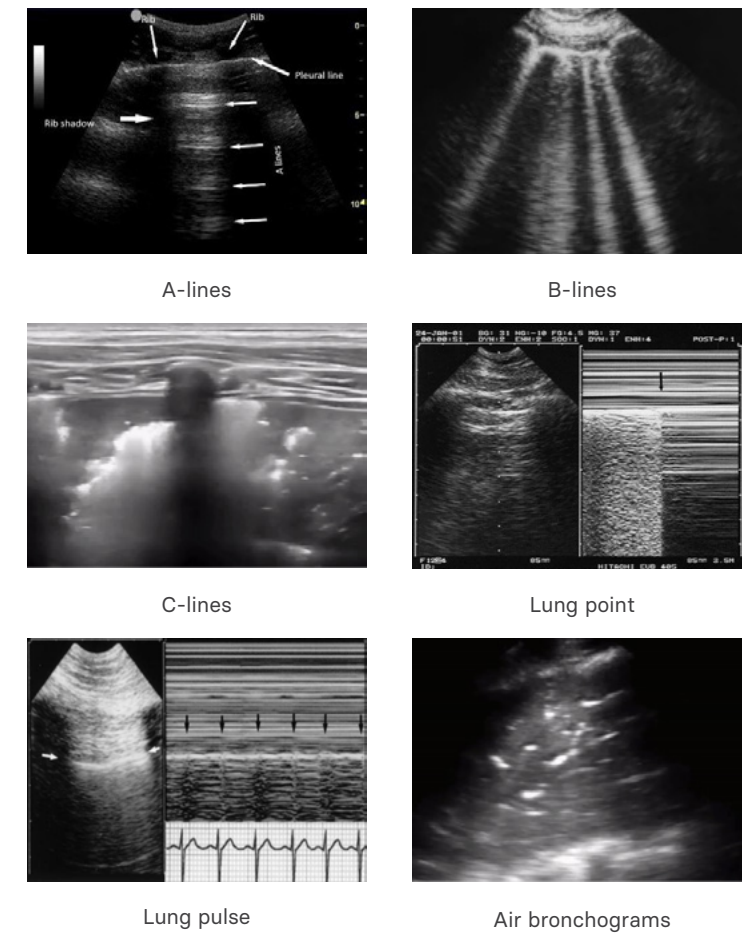
Table 2. Commonly used lung signs

Finding	Features	Interpretation
A-line <i>Other names: horizontal reverberation artefact, air artefact lines, repetitive pleural artefacts</i>	Horizontal, hyperechoic Each reverberation fades	Presence of air Does not distinguish between alveolar and pleural air (i.e. present in both well-aerated lung and in pneumothorax)
A profile	Lung sliding present	
A' profile	No lung sliding present	A profile without lung sliding
B-line <i>Other names: comet-tail artefact, ultrasound lung comets</i>	Hydroaeric comet-tail artefact Arises from pleural line Hyperechoic Well-defined Spreading up indefinitely (spread to edge of screen without fading) Erasing A-lines Moves with lung sliding when lung sliding present	Associated with Kerley B-lines Focal B-lines can be normal or associated with: - Pneumonia/pneumonitis - Atelectasis - Pulmonary contusion, infarction or neoplasia - Pleural disease Multiple diffuse bilateral B-lines are associated with: - Pulmonary oedema - Interstitial pneumonia or pneumonitis - Diffuse parenchymal lung disease/pulmonary fibrosis

<p>B pattern</p> <p><i>Other names: B profile, B+ lines, lung rockets</i></p> <p>B7 lines (septal rockets)</p> <p>B3 lines (ground-glass rockets)</p> <p>Confluent/coalescent B-lines (white lung)²⁵</p>	<p>Three or more B-lines in an intercostal space</p> <p>B7: a distance of 6.0-7.0 mm between two B-lines</p> <p>B3: a distance \leq 3.0 mm between two B-lines</p> <p>Confluent: when numerous B-lines are in close proximity, they become confluent (qualitative description and no clear definition as to what constitutes this)</p>	<p>It was initially thought that B3/B7 lines could distinguish between interstitial (B7) and alveolar (B3) oedema, but growing evidence demonstrates B-line morphology is influenced by many technical factors²⁶</p> <p>B7 is associated with thickened interlobular septi on CT, B3 with ground glass opacity on CT</p> <p>The degree of B-line fusion is related to lung water content and degree of pulmonary oedema, but not interstitial versus alveolar involvement</p>
B profile	B pattern that is anterior, bilateral, disseminated and associated with lung sliding	Associated with haemodynamic pulmonary oedema
B' profile	B profile without lung sliding	Associated with pneumonia or ARDS
A/B Profile	A profile in one lung, B profile in other lung (at upper and lower BLUE points)	Pneumonia in the lung with B-profile
<p>C-line</p> <p><i>Other names: fractal line, pleural shredding, shred line</i></p>	<p>The term "C-line" is not standardised</p> <p>Referred to as hypoechoic subpleural focal areas (irregular, jagged appearance of pleural line); or,</p> <p>Comet-tail artefact originating from fractal line</p>	<p>Represent condensed lung tissue, typically seen in conditions like atelectasis or pneumonia²⁷</p> <p>Seen with small pleural consolidations at the edge of consolidated and normal, aerated lung</p>
C profile	Consolidation on upper or lower BLUE points	Represents pneumonia
Lung point	The point where visceral pleural separates from parietal pleura	<p>Specific for pneumothorax</p> <p>Absence does not rule out pneumothorax</p>
Lung pulse	<p>Cardiogenic oscillations seen on pleural interface</p> <p>Easier to detect using M-mode and identifying T-lines</p>	<p>Indicates parietal and visceral pleura in opposition</p> <p>Presence excludes pneumothorax</p>
Air bronchograms	<p>Hyperechoic, branching or punctate structures seen within consolidated lung</p> <p>Bronchograms that move with respiration are dynamic</p>	<p>Static: suggestive of atelectasis or complete airway obstruction; however, can be seen in pneumonia²⁸</p> <p>Dynamic: suggestive of pneumonia</p> <p>Colour doppler also helpful to distinguish between atelectasis and pneumonia:</p> <ul style="list-style-type: none"> - Atelectasis: likely absent due to hypoxic pulmonary vasoconstriction (HPV) - Pneumonia: likely present due to impaired HPV²⁰

Terminology including "false B-lines" named I-lines, E-lines, and Z-lines, and alveolar-interstitial syndrome, are beyond the scope of this article

Figure 5. Artefact lines used in scanning protocols



Ultrasound images of A-lines, B-lines, C-lines/shred sign, lung point, lung pulse (arrow: T-lines), air bronchograms. Images reproduced from Rao (2022),²⁹ Lichtenstein (2014),³⁰ Ross & Joffe (2017),³¹ and Lichtenstein et al. (2003)³²

INDICATIONS

Preoperative

- Assess patients with chest pain, tachypnoea, dyspnoea.
- Identify patients at risk of postoperative pulmonary complications (PPCs).
- Identify the cause of preoperative hypoxaemia (e.g. large bilateral pleural effusions).
- Identify pneumothorax and the risk of initiating positive pressure ventilation.
- Identify pleural adhesions before thoracic surgery.³³

Intraoperative

- Differentiate the causes of intraoperative hypoxaemia.
- Identify iatrogenic injury (e.g. capnothorax).
- Screen for pneumothorax after central venous catheter (CVC) insertion.

- Monitoring lung recruitment and ventilation strategies.
- Assessing haemodynamic status: aids in diagnosing pulmonary congestion and guiding fluid management in unstable patients.
- Peri-arrest assessment to rule out pneumothorax.

Postoperative

- Identify the cause of hypoxia, hypotension, dyspnoea, and chest pain.
- Identify the risk of postoperative deterioration to plan disposition.

LIMITATIONS

LUS accuracy significantly depends on operator characteristics, such as ideal image acquisition technique and replicable conditions for serial examinations to allow comparison. Image acquisition can be further limited by patient and intraoperative barriers to the probe (such as in breast and cardiothoracic surgery); an inability to abduct arms for positioning at the posterior axillary line, which gives access to the posterior lateral alveolar and/or pleural syndrome (PLAPS) views (see Figure 3); and the presence of dressings or subcutaneous emphysema. Finally, there are risks of thermal and mechanical bioeffects, particularly to a fetus, premature neonate or infant, though these have never proven harmful in humans.¹⁵

PERFORMANCE, LEARNING AND RELIABILITY

LUS has a more accessible learning curve compared to echocardiography due to simpler anatomy and fewer standardised windows. Image acquisition is generally straightforward; however, interpreting artefacts and distinguishing subtle findings presents a steeper learning challenge.

Studies have demonstrated high inter-observer agreement,³⁴ reflecting strong reliability when performed by trained clinicians. In the perioperative setting, LUS is readily accessible, with probes and machines already in everyday use.

Practical training should include a combination of theoretical instruction, practical hands-on sessions under supervision, and case-based reviews of common pleuro-pulmonary pathologies.¹⁵ Notably, LUS training can be extended beyond physicians, with applications for allied health professionals such as physiotherapists and paramedics. There is also growing advocacy for integrating LUS training into medical school curricula, positioning it as a modern extension of the physical examination, with diagnostic accuracy surpassing that of the stethoscope.

ANZCA's *Guideline on training and practice of perioperative diagnostic point-of-care ultrasound (POCUS) 2025* recommends formal education through didactic content or obtaining a specialist certification. This includes 20 supervised studies, 20 additional unsupervised studies with supervisor review, and the review of 10 pre-recorded cases.³⁵

Evidence from a study based in a low-resource setting demonstrated that practical competence could be achieved after just five supervised scans; however, proficiency required an additional five independent scans.³⁶ Importantly, ongoing competence was not assessed in this cohort. In contrast, another study recommended 20–25 supervised scans to develop basic interpretive skills in LUS,³⁷ likely reflecting the complexity of ICU patient presentations compared to those in the emergency department or perioperative settings. This disparity underscores the need to tailor training recommendations according to clinical context.

While LUS adds to the clinician's workload, the time required to perform a comprehensive lung aeration assessment is relatively modest – approximately 8 minutes for experienced users and 10 minutes for trainees,³⁸ and less than 3 minutes for the BLUE protocol.⁸

ALGORITHM IN THE PERIOPERATIVE SETTING

Due to the clinical urgency of severe hypoxaemia, LUS in the perioperative setting must balance speed and accuracy. After reviewing existing protocols, we recommend following Kruisselbrink's I-AIM protocol as a framework, but scanning three key zones bilaterally as described in the BLUE protocol, using a well-established common language familiar to anaesthetists and other critical care clinicians. Various protocols

describe anywhere from 6 to 28 zones to scan to increase accuracy and information gathering; this can be attempted if time permits for a more comprehensive assessment.

With any protocol, LUS should answer the following questions:

- **Is there lung sliding?** If not, is there a lung point?
- **Are B-lines present?** How many and where?
- **Is the pleural line irregular?**
- **Is there hepatisation of the lung?**
- **Is there free thoracic fluid?** What are the size and fluid characteristics?

Three key scanning zones

The hand placement method described in the original BLUE protocol may be ergonomically difficult to apply intraoperatively due to variable patient body sizes and positioning constraints.^{8,39} Instead, identifying landmarks based on intercostal spaces and anatomical lines may be a more practical approach. These are summarised below and presented in Figure 6.

1. Anterior (upper BLUE point)

- **Location:** 2nd intercostal space, mid-clavicular line (most anterior chest in supine position).
- **Findings:** Lung sliding, A-lines (normal aeration), B-lines (interstitial syndrome, pulmonary oedema).

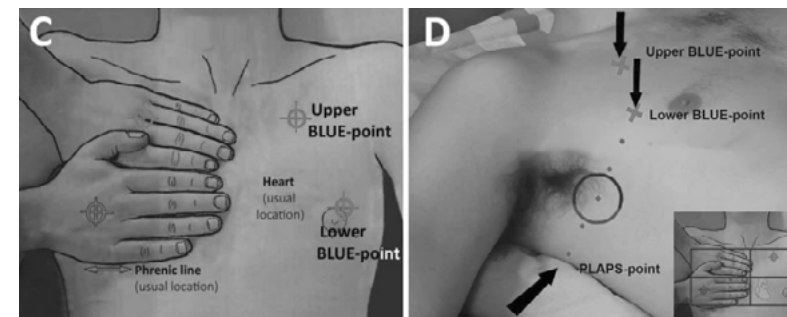
2. Lateral (lower BLUE point)

- **Location:** 4th intercostal space, anterior axillary line.
- **Findings:** Lung sliding, A-lines, B-lines (suggesting alveolar-interstitial syndrome), effusions.

3. PLAPS (posterolateral alveolar and/or pleural syndrome) point

- **Location:** Horizontal continuation of the lower BLUE point, as posterior as possible towards the posterior axillary line.
- **Findings:** B-lines, consolidation (pneumonia, atelectasis), pleural effusions.

Figure 6. BLUE protocol scanning zones



Reproduced from Bar et al. (2022)⁴⁰

Kruisselbrink's protocol

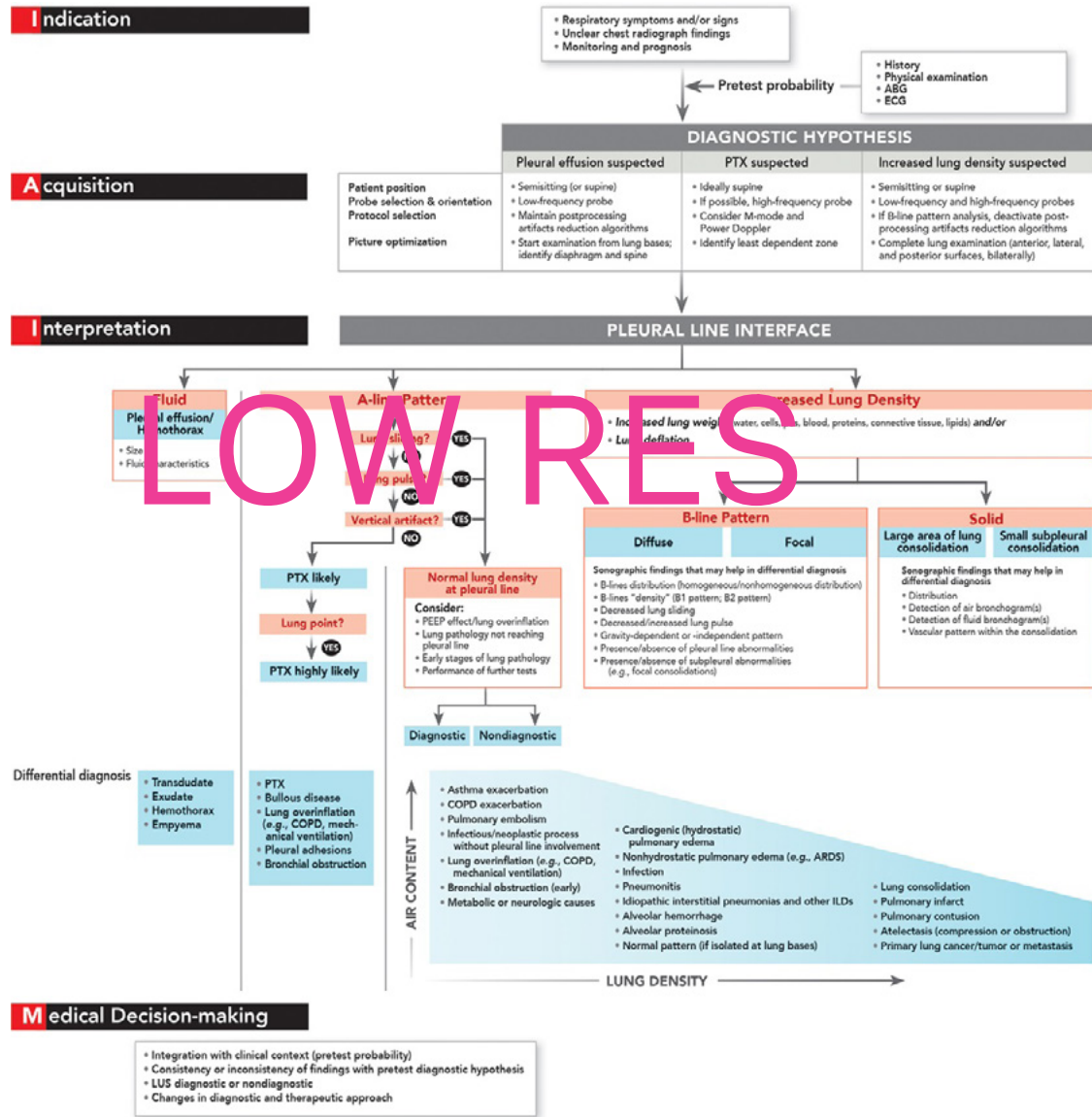
Kruisselbrink's LUS protocol provides an excellent framework to follow, applying the broad "Indication, Acquisition, Interpretation, and Medical decision-making" (I-AIM) cognitive scaffold for trainees learning LUS.⁴¹ It also considers a wider range of differentials, particularly in the perioperative and intensive care settings.

Indication and acquisition steps optimise scanning for the suspected pathology. Interpretation provides a simple breakdown of findings to narrow the differential diagnoses. Medical decision-making emphasises placing the interpretations into context, including determining if the scan is diagnostic. This is important as differential diagnoses can produce overlapping ultrasound artefacts.

Limitations of this protocol include a lack of practitioner familiarity, a lack of disease-specific ultrasound profiles or defined pathological findings, and no guidance over acquisition technique, which may reduce consistency.

If time and relevancy permit, additions could include a comprehensive LUS assessment viewing the posterior zones, incorporating echocardiography to improve diagnostic certainty, particularly for pulmonary embolism and acute pulmonary oedema, and assessing diaphragmatic motion for phrenic nerve palsy. Krusselbrink's protocol is graphically presented in Figure 7, and a guide for helpful interpretation of clinically relevant findings is presented in Table 3.

Figure 7. I-AIM framework for lung ultrasound



Reproduced from Krusselbrink et al. (2017)⁴¹

Table 3. Key LUS findings and interpretation of the most common intraoperative causes of severe perioperative hypoxaemia

Diagnosis	LUS features		Interpretation
	Present	Absent	
Fluid			
Pleural effusion	Sinusoid sign (respiratory variation reducing parietal and visceral pleura distance on M-mode) Quad sign Spine sign Jellyfish sign	A- or B-lines over fluid zone Curtain sign	Found in dependent zones, unless complex effusion Consider drainage or diuresis Qualitative - Transudates – anechoic, non-septated fluid, homogenous - Exudates – complex, echogenic, septated fluid, debris, organised clots, pleural thickening more likely Quantitative - Formulas (such as the Balik formula) have been proposed to estimate effusion volumes - Lack validation and are unreliable for complex or exudative effusions - Routine use is not advised
A-line pattern			
Normal lung or Bronchospasm	A-lines Lung sliding B-lines (two or fewer)	B-lines (more than two) Consolidation Lung point Lung pulse	Normal LUS helps exclude parenchymal or intrapulmonary causes
Endobronchial intubation	Bilateral A-lines Lung pulse in non-ventilated lung	B-lines (early stage only) and lung sliding in non-ventilated lung Lung point	Resolves with re-positioning of ETT
Pneumothorax	A-lines Lung point	Lung sliding B-lines Lung pulse	Lack of lung sliding highly sensitive Lung point highly specific
Mucus plugging	Lung sliding A-lines Scattered B-lines Small subpleural consolidation	Lung point	Rule out other causes (e.g. pneumothorax) May need suction or bronchoscopy

Pulmonary embolus	A-lines Lung sliding May see peripheral, wedge-shaped subpleural consolidation	B-lines Lung pulse Lung point	Normal B-line pattern excludes APO/ARDS Use TTE Can follow BLUE protocol to look for lower limb DVT
Increased lung density pattern			
Atelectasis	Focal B-lines or hepatisation Static air bronchograms Lung sliding (normal or reduced) Lung pulse	Lung point A-lines	Improves with recruitment/PEEP
Pulmonary oedema	Bilateral diffuse B-lines Lung sliding	Lung pulse Lung point	Cardiogenic = bilateral, symmetric, diffuse B-lines
Pneumonia	Lung sliding (although B' profile possible but rare) Localised, asymmetric B-lines Pleural shred/fractal line Dynamic air bronchogram Hepatisation (lung sign)	A-lines in affected area Lung point Lung pulse unlikely	Localised, dependent Evolves over time with serial LUS

EXAMPLE SCENARIOS – BASED ON ACTUAL CASE REPORTS

Case 1

Case sourced from Han et al. (2020)⁴²

A 73-year-old female with acute gallstone cholecystitis was planned for emergency laparoscopic cholecystectomy. She had a background of coronary artery disease with previous PCI, hypertension and type 2 diabetes. Her pre-induction vital signs were BP 170/100 mmHg, HR 90, SpO₂ 96% on room air. She had an uneventful induction of anaesthesia and tracheal intubation, with good bilateral air entry on auscultation and peak airway pressures of 14 cmH₂O.

Following an ultrasound-guided TAP block, surgery commenced, and pneumoperitoneum was established with intra-abdominal pressures less than 14 cmH₂O and peak airway pressures of 20 cmH₂O. After 15 minutes, the position was changed to reverse Trendelenburg with a left tilt to facilitate the surgery. At this time, the peak airway pressure jumped to 28 cmH₂O, and the ETCO₂ also rose to 55, along with a fall in SpO₂ to 88% despite increasing the FiO₂ to 0.9. Other haemodynamic parameters were normal. Left lung auscultation was normal, with no air entry to the right. A right mainstem bronchus intubation was suspected; however, it was quickly ruled out using a bronchoscope, which demonstrated the ETT tip above the carina and no mucus plugging in the right lung. LUS was then performed, demonstrating lung sliding present on the left but absent on the right chest (an example of this is presented in Figures 8 and 9). The

surgeon then inspected the diaphragm in detail and discovered a 1 cm defect in the right hemidiaphragm. The right lung atelectasis caused by the capnothorax was slowly resolved with PEEP and recruitment, and the diaphragmatic defect was sutured by the surgeon.

Figure 8. Right lung demonstrating stratosphere sign, indicating lack of lung sliding

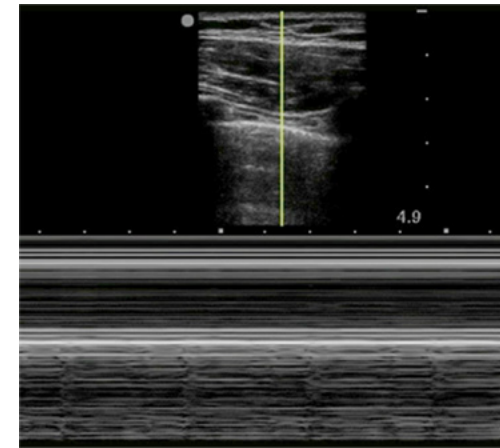
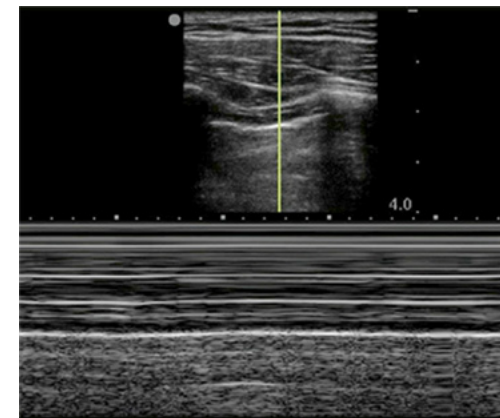


Figure 9. Left lung demonstrating sandy beach sign, indicating normal lung sliding



Case 2

Case sourced from Zhang et al. (2021)⁴³

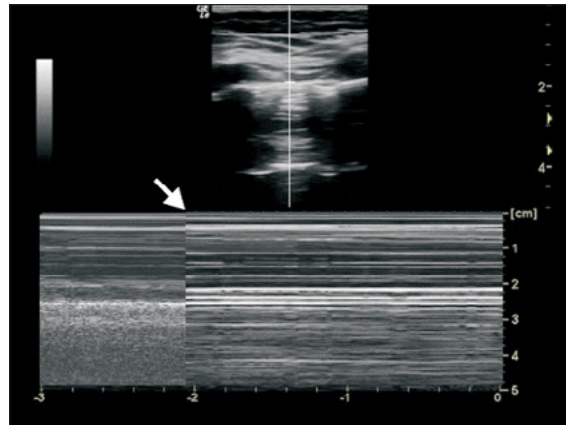
A 53-year-old male was admitted following a fall. An eFAST scan was performed in the emergency department, which demonstrated splenic rupture with intra-abdominal fluid. This was associated with progressive anaemia but no cardiac or thoracic abnormalities on ultrasound. A preoperative CT scan did not demonstrate a haemothorax or pneumothorax. Vital signs prior to induction were BP 126/82 mmHg, HR 75, SpO₂ 95% on room air.

Following induction of anaesthesia and tracheal intubation, positive airway pressure was applied, noting a peak airway pressure of 14 cmH₂O at this time. Breath sounds were difficult to auscultate bilaterally due to a thick chest wall. Two minutes after intubation, the patient became progressively more difficult to ventilate, with a peak airway pressure reaching 50 cmH₂O and a SpO₂ nadir of 70%.

A rapid LUS was performed, which demonstrated a lack of pleural sliding in the left upper and lower BLUE points. The lung point (see Figure 10) was visualised with lateral sliding of the probe, confirming the diagnosis and boundary of the pneumothorax. A chest drain was inserted with ultrasound guidance,

resulting in immediate improvement of oxygen saturations and airway pressures. The time interval between initial suspicion of a pneumothorax until insertion of the chest drain was less than 3 minutes.

Figure 10. Example of lung point seen on M-mode



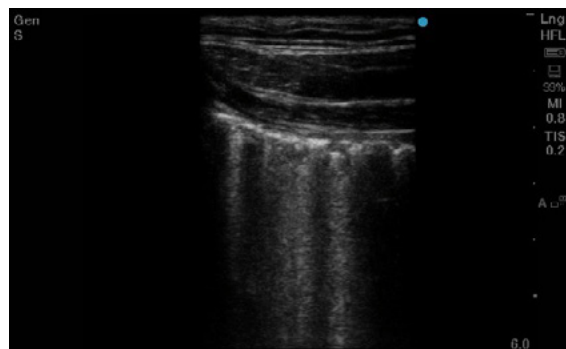
Lung point indicated by white arrow. Image sourced from Song (2018)¹⁴

Case 3

Case sourced from Dai et al. (2024)⁴⁴

A 55-year-old female was planned for an elective hysteroscopic myomectomy to resect a submucosal uterine leiomyoma. She had a background of untreated hypertension and smoking. Her preoperative physical examination, ECG and CXR were all unremarkable. Her pre-induction vital signs were BP 175/98, HR 75 and SpO₂ 96% on room air. General anaesthesia was induced, an LMA was placed and the patient was positioned in lithotomy. Positive pressure ventilation was commenced in VCV mode, with saturations of 99–100% on FiO₂ 0.4. The surgical uterine dilation was 0.9% saline, with uterine dilation pressure of 100 mmHg. Thirty minutes into the operation, a gradual drop in SpO₂ and ETCO₂ was observed. LUS demonstrated diffuse B-lines (see Figure 11) in both lungs and a diagnosis of operative hysteroscopy intravascular absorption (OHIA) syndrome was made. Saturations improved following diuresis with IV frusemide and after thorough surgical haemostasis, the operation was concluded. The patient emerged well without an oxygen requirement and the B-lines were largely resolved on repeat LUS in the post-anaesthesia care unit.

Figure 11. Example of B-lines

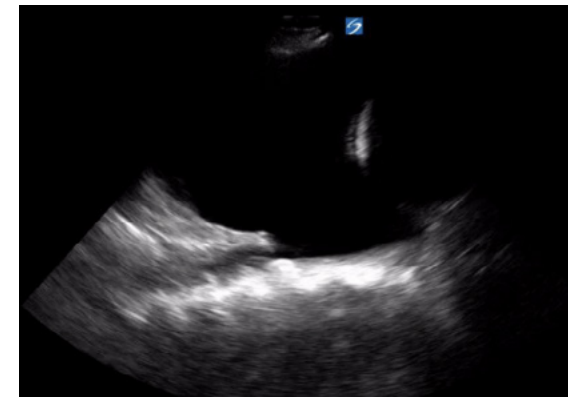


Case 4

Case sourced from Leech et al. (2015)⁴⁵

A 56-year-old male was admitted to ICU with hypoxia secondary to left lung pneumonia. He was having issues with worsening hypoxia, and mucus plugging was suspected due to secretion retention and a left hemithorax white-out on chest radiograph. This was managed by the physiotherapist with airway clearance techniques, patient positioning and nasopharyngeal suctioning. While this improved secretion removal, the patient continued to experience ongoing high work of breathing and increasing oxygen requirements. The physiotherapist then performed a LUS, which revealed a large pleural effusion, which was subsequently drained by the medical team. Over 1500 mL was drained, which dramatically improved the patient's work of breathing and oxygen requirements, avoiding further escalation of treatment such as intubation and mechanical ventilation. An example of what this would look like on curvilinear ultrasound is presented in Figure 12.

Figure 12. Example of a large pleural effusion with spine sign



FUTURE DIRECTION

LUS is an increasingly valuable tool for perioperative physicians, offering rapid, non-invasive assessment of respiratory pathology and complementing clinical examination, auscultation, and other bedside monitoring. Like basic echocardiography, we anticipate that LUS will become a standard skill in the perioperative setting, aiding real-time clinical decision-making when interpreted within the broader clinical context and pre-test probability. However, it is essential to remember that ultrasound findings are part of the diagnostic puzzle, and patient management should always prioritise the clinical picture rather than isolated imaging results.

Despite its utility, LUS does present an additional workload and time commitment, particularly for those early in their learning curve. Currently, there is variability in training standards and credentialing, which underscores the need for formal, competency-based education pathways. Future directions should focus on the development of standardised training programs, assessment tools, and simulation-based learning platforms to ensure widespread proficiency. As the technology continues to evolve and become more accessible, further research will help define its role across different clinical settings, optimise scanning protocols, and refine its integration into routine perioperative care.

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