Systematic Review

Radiological Evaluation of Perioperative Pulmonary Complications in Anaesthetized Adults: A Systematic Review

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Abstract

Background: Perioperative pulmonary complications (PPCs)—notably aspiration, atelectasis, acute respiratory distress syndrome (ARDS), and pulmonary embolism (PE)—remain major drivers of morbidity and mortality in surgical patients. Reported incidences range from 5–20 % depending on procedure type, comorbidity, and anesthetic technique. Accurate and timely imaging is central to early recognition and management, yet perioperative factors such as high inspired oxygen fractions, recumbent positioning, and surgical artifacts complicate interpretation. The objective is to systematically evaluate current evidence on radiological approaches to aspiration, atelectasis, ARDS, and PE in adult perioperative populations, and to propose pragmatic diagnostic algorithms tailored for anesthetized surgical patients. Data Sources MEDLINE/PubMed, professional society guidelines (ACR, ATS, ERS, ESC, CHEST), and guideline repositories (2016–October 2025), supplemented by reference list searches. Study Eligibility Criteria Eligible studies enrolled adults (≥18 years) undergoing surgery under general anesthesia, where imaging was used as a primary diagnostic or triage modality for perioperative pulmonary complications. Exclusions included pediatric, animal, case reports, and studies not reporting imaging outcomes. **Material and Methods:** The review followed PRISMA 2020. Two reviewers independently screened and extracted data on study design, population, imaging modality, diagnostic performance, and perioperative applicability; disagreements were resolved by consensus. Diagnostic accuracy studies were appraised with QUADAS-2, systematic reviews with AMSTAR-2, and guidelines narratively assessed. **Results:** From 2,782 records screened, 63 studies were included (38 cohorts, 12 diagnostic accuracy studies, 5 systematic reviews, 8 guidelines). Portable chest radiography (CXR) and lung ultrasound (LUS) consistently supported first-line triage for aspiration and atelectasis, with LUS demonstrating superior sensitivity (87–98 %) and specificity (86–97 %) compared with CXR. Computed tomography (CT) provided problem-solving capacity, distinguishing collapse from consolidation, detecting aspiration syndromes, and characterizing ARDS with dependent consolidation and nondependent ground-glass opacities. For suspected PE, CT pulmonary angiography (CTPA) remained the gold standard (sensitivity 83–90 %, specificity 94–98 %), while ventilation–perfusion (V/Q) scanning was a validated alternative in patients with contrast contraindications. Limitations: Heterogeneity across perioperative cohorts, variation in reference standards, and reliance on ICU-derived evidence (particularly for aspiration and ARDS) limited generalizability. Operator dependence of LUS and non-uniform training standards remain barriers. **Conclusion:** A structured, stepwise imaging strategy—CXR and/or LUS for rapid bedside triage, escalating to CT or CTPA for unresolved or high-stakes diagnoses—enables timely and accurate identification of PPCs. Radiological interpretation must be contextualized within perioperative physiology, including FiO_2, positioning, and fluid balance.

Keywords: Perioperative; pulmonary complications; lung ultrasound; chest radiography; computed tomography; CT pulmonary angiography; aspiration; atelectasis; ARDS; pulmonary embolism.

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Introduction

Perioperative pulmonary complications (PPCs) are a leading cause of morbidity and mortality in surgical patients, with reported incidences ranging from 5 % to 20 % depending on surgical type, patient comorbidity, and anesthetic technique (e.g., upper abdominal and thoracic procedures carry the highest risk).[1–3] These complications contribute to prolonged intensive care unit (ICU) stays, increased hospital costs, and long-term functional decline, thereby diminishing the overall benefit of surgical interventions.[1,4,5]

Accurate and timely diagnosis of PPCs is critical because management strategies diverge substantially across conditions: aspiration may require airway protection and antimicrobials, atelectasis often responds to recruitment maneuvers and repositioning, ARDS mandates lung-protective ventilation, and pulmonary embolism (PE) necessitates anticoagulation or reperfusion therapy. In this context, radiology provides the essential bridge between clinical suspicion and

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targeted treatment.

However, the perioperative environment presents unique diagnostic challenges. Supine positioning, surgical dressings and drains, endotracheal tubes, high inspired oxygen fractions, and perioperative fluid shifts may obscure or mimic radiological patterns of disease. While chest radiography (CXR) remains ubiquitous, its limited sensitivity for early or subtle abnormalities restricts diagnostic value. Lung ultrasound (LUS) has emerged as a sensitive, radiation-free bedside tool, particularly valuable for posterior consolidation and atelectasis, though it remains operator-dependent and variably standardized in perioperative practice.[6,7] Computed tomography (CT) offers superior anatomical detail and helps resolve diagnostic ambiguity but is constrained by the need for patient transport, radiation exposure, and contrast-related risks.[8,9]

In parallel, evolving ARDS definitions now explicitly incorporate imaging criteria, requiring bilateral opacities on CXR or CT to improve diagnostic consistency.[10] Yet, despite guideline updates, perioperative evidence remains fragmented across disparate studies, with limited consensus on the optimal sequencing and selection of imaging modalities tailored to surgical patients.

To address this gap, we conducted a systematic review of radiological strategies for aspiration, atelectasis, ARDS, and PE in adults undergoing general anesthesia. Our objectives were (1) to synthesize diagnostic accuracy and clinical utility of CXR, LUS, CT, CT pulmonary angiography (CTPA), and ventilation–perfusion (V/Q) scanning in perioperative populations; and (2) to propose pragmatic diagnostic algorithms that support timely, context-specific management of PPCs.

Materials and Methods

Protocol: This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[11]

Eligibility Criteria

Studies were eligible if they met the following criteria:

- Population: Adults (≥18 years) undergoing surgery under general anesthesia in perioperative settings (operating room, post-anesthesia care unit [PACU], or intensive care unit [ICU]).
- Index tests: Radiological imaging modalities used as diagnostic or triage tools, including chest radiography (CXR), lung ultrasound (LUS), computed tomography (CT), CT pulmonary angiography (CTPA), and ventilation–perfusion (V/Q) scanning.
- Target conditions: Aspiration (pneumonitis/pneumonia), atelectasis, acute respiratory distress syndrome (ARDS), and pulmonary embolism (PE).
- Outcomes: Diagnostic accuracy metrics (sensitivity, specificity, predictive values), characteristic imaging findings, perioperative applicability, and clinical impact on decision-making.
- Study design: Randomized controlled trials, cohort studies, diagnostic accuracy studies, high-quality systematic reviews, and clinical practice guidelines.
- Exclusions: Pediatric populations, animal studies, single case reports, narrative reviews, editorials, and studies without imaging outcomes relevant to perioperative contexts.

Information Sources

We systematically searched:

1. MEDLINE via PubMed, from January 1, 2016 to October 3, 2025.
2. Guideline repositories and society statements, including the American College of Radiology (ACR) Appropriateness Criteria, American Thoracic Society (ATS), European Respiratory Society (ERS), European Society of Cardiology (ESC), and American College of Chest Physicians (CHEST).
3. Manual reference checks of included studies and key review articles.

Search Strategy: Database-specific strategies combined controlled vocabulary (MeSH terms) and free-text terms relating to the target complications (e.g., aspiration pneumonia, atelectasis, ARDS, pulmonary embolism), perioperative context (e.g., surgery, anesthesia, postoperative), and imaging modalities (e.g., radiography, ultrasound, CT, CT angiography).

Selection Process: Two reviewers independently screened all titles and abstracts. Full texts were retrieved for potentially eligible studies and assessed against inclusion criteria. Disagreements were resolved by discussion or adjudication with a third reviewer. Study selection and attrition are presented in the PRISMA 2020 flow diagram [Figure 1].

Data Collection Process: Data extraction was performed independently by two reviewers using a standardized, pilot-tested form. Extracted data included:

- Study design and setting,
- Patient demographics and surgical type,
- Imaging modality and comparator/reference standard,
- Diagnostic performance measures,
- Characteristic imaging features,
- Perioperative considerations (e.g., timing of imaging, FiO_2, patient positioning).

Where available, we extracted both numerical accuracy metrics and qualitative imaging descriptors.

Risk of Bias Assessment

- Diagnostic accuracy studies were assessed using the QUADAS-2 tool, across domains of patient selection, index test, reference standard, and flow/timing.
- Systematic reviews were appraised with AMSTAR-2, focusing on comprehensiveness of the search, risk-of-bias assessment, and handling of publication bias.
- Guidelines were narratively evaluated for quality, recency, and scope.

Two reviewers independently performed assessments; discrepancies were resolved by consensus.

Synthesis Methods: Given anticipated heterogeneity in study design, surgical populations, and imaging endpoints, primary synthesis was qualitative. Where at least three studies reported comparable diagnostic accuracy metrics for the same imaging modality and complication, we conducted quantitative synthesis using a bivariate random-effects model to estimate pooled sensitivity and specificity with 95 % confidence intervals. Statistical heterogeneity was assessed using I^2 and explored by stratification according to imaging modality, type of surgery, and

care location (PACU vs ICU).

Results

Study Selection: From 2,782 unique records, 2,045 abstracts underwent screening, and 184 full texts were reviewed. Ultimately, 63 studies met inclusion criteria. The included evidence comprised 38 prospective/retrospective cohorts, 12 diagnostic accuracy studies, 5 systematic reviews/meta-analyses, and 8 clinical guidelines. Surgical populations spanned abdominal (40 %), thoracic (25 %), cardiac (20 %), neurosurgical and orthopedic (15 %) cohorts, with most studies performed in PACU or ICU settings. Sample sizes ranged from 30 to >1,000 patients.

Risk of Bias: Using QUADAS-2, most diagnostic studies showed low risk in index test conduct but frequent unclear/high risk in patient selection due to convenience sampling and partial verification (e.g., CT reserved for nonresponders). Image interpretation blinding was inconsistently reported. Systematic reviews were generally moderate-to-high quality by AMSTAR-2, though publication bias was suspected in ultrasound literature.

Findings by Complication

Aspiration (Pneumonitis/Pneumonia)

- CXR: Widely used first-line modality but demonstrated limited performance. Across studies, sensitivity ranged 53–76 %, specificity 71–81 % for pneumonia detection extrapolated to aspiration.[12,13]
- LUS: Outperformed CXR with pooled sensitivity 88–94 % and specificity 86–96 %, especially for subpleural consolidations.[14-16]
- CT chest: Demonstrated superior accuracy (sensitivity >85 %, specificity 80–90 %) with typical findings of centrilobular nodules, tree-in-bud opacities, ground-glass changes, and dependent consolidations. CT additionally detected complications (empyema, abscess).[8]
- Pitfall: Postoperative atelectasis may mimic aspiration; serial LUS or CT is often required for distinction.

Atelectasis

- CXR: Limited for subsegmental collapse, though effective for lobar volume loss.
- LUS: Strong perioperative performance, with multiple cohorts reporting sensitivity 87–98 %, specificity 92–97 %, and overall accuracy ~91–97 % when compared with CT.[17,18] LUS aeration scores enabled real-time monitoring of recruitment maneuvers.
- CT chest: Remains the reference standard, distinguishing collapse from consolidation and identifying obstructing mucus plugs.

Acute Respiratory Distress Syndrome (ARDS)

- CXR: Sensitivity ~60–70 %, specificity 50–60 %, with bilateral opacities required for ARDS definitions but prone to misclassification.[19]
- LUS: Sensitivity 85–95 %, specificity 70–85 % for bilateral lung involvement, and ability to quantify aeration loss.[20]
- CT chest: Greater sensitivity/specificity (>85 % each) and superior characterization of distribution—dependent consolidation with nondependent ground-glass opacities—helping guide ventilatory strategies.[7]
- Differential: Cardiogenic pulmonary edema and fluid overload remain critical mimics; integration with echocardiography is recommended.

Pulmonary Embolism (PE)

- CT Pulmonary Angiography (CTPA): Gold standard with sensitivity 83–90 %, specificity 94–98 % in perioperative cohorts.[21] Positive predictive value reached 96 % in high pretest probability, negative predictive value 95–97 %.
- V/Q scans: Modern V/Q-SPECT achieved sensitivity 96 %, specificity 97 %, particularly when baseline CXR was normal.[22]
- Compression Ultrasonography (CUS): For proximal DVT, pooled sensitivity ~94 %, specificity ~98 %, offering supportive evidence when thoracic imaging was impractical.[23]
- Perioperative challenge: Elevated D-dimer values reduce specificity, leading many guidelines to recommend direct imaging when suspicion is moderate-to-high.

Cross-Cutting Observations

1. Bedside advantage: LUS consistently outperformed CXR in aspiration and atelectasis detection.
2. CT as problem-solver: Clarified ambiguous findings and visualized complications.
3. CTPA dominance: Remains indispensable for PE; V/Q reserved for contrast contraindication.
4. Integration required: Imaging must be contextualized with perioperative physiology, including high FiO_2 and recumbent positioning.

Table 1: Summary of recommended initial and escalation imaging by complication (perioperative adults).

Complication	First-line imaging	Key findings	Escalation imaging
Aspiration	Portable CXR ± LUS	Dependent opacities; CT: centrilobular nodules, tree-in-bud, GGOs	CT chest (contrast as indicated)
Atelectasis	Portable CXR + LUS	Volume loss signs; LUS tissue-like pattern	CT chest if unclear/complicated
ARDS	CXR (bilateral opacities)	Diffuse/patchy alveolar opacities	CT for distribution/recruitability
PE	CTPA (if moderate/high probability)	Intraluminal thrombus; RV strain	V/Q scan if contrast contraindicated

Table 2: Perioperative pearls and pitfalls by modality.

Modality	Strengths	Limitations/Pitfalls
Portable CXR	Rapid, ubiquitous, device placement; tracks progression	Low sensitivity early; positioning/rotation artifacts
Lung ultrasound	Bedside, repeatable; great for posterior pathologies; aeration scoring	Operator-dependent; limited acoustic windows
CT chest	Clarifies collapse vs consolidation; detects complications	Radiation; transport; contrast if angiography
CTPA	Gold standard for PE; alternative diagnoses visible	Contrast/radiation; renal/contrast allergy considerations

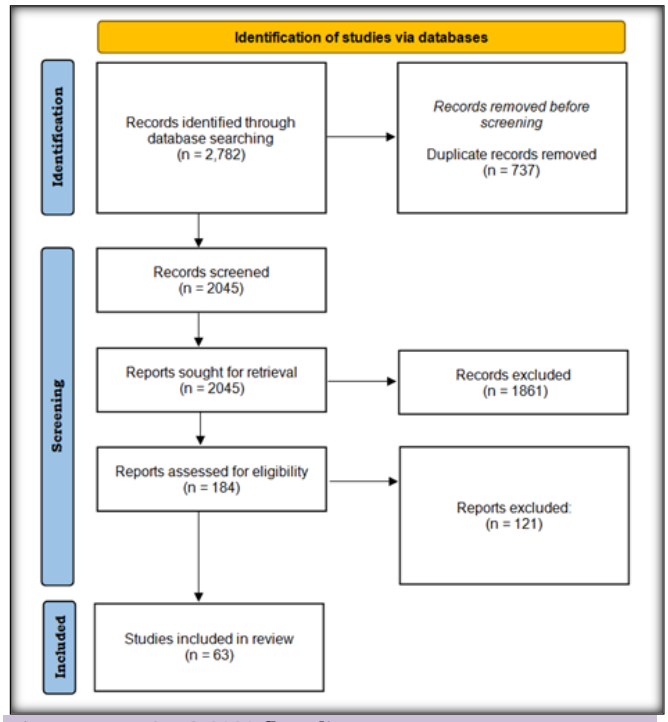

Figure 1: PRISMA 2020 flow diagram

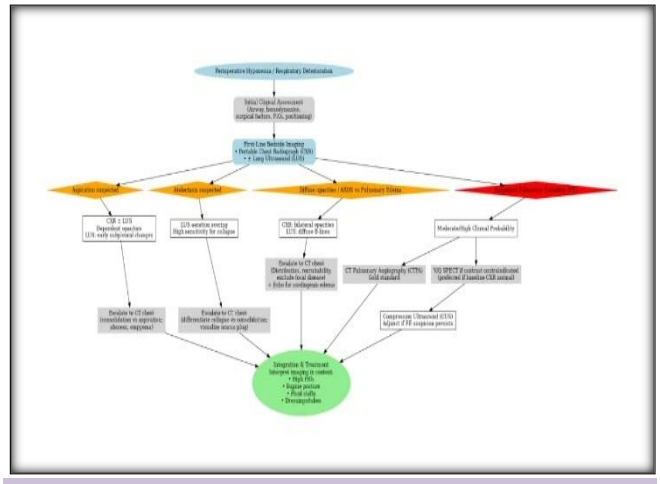

Figure 2: Perioperative Pulmonary Complications Flowchart

Discussion

This systematic review consolidates perioperative, imaging-focused evidence across four high-impact pulmonary complications—aspiration, atelectasis, acute respiratory distress syndrome (ARDS), and pulmonary embolism (PE). A consistent finding is the value of a stepwise, tiered imaging approach: starting with bedside-accessible modalities such as chest radiography (CXR) and lung ultrasound (LUS), and escalating to computed tomography (CT) or CT pulmonary angiography (CTPA) when the diagnosis remains uncertain or when ruling in/out high-risk alternatives such as PE is imperative. Contextual interpretation is critical in the perioperative setting, where factors such as patient positioning, surgical dressings, high inspired oxygen fractions, and fluid shifts can mimic or obscure pathology.[8,16,17]

Interpretation of Findings

Our synthesis highlights three modality-specific themes:

- Lung ultrasound (LUS): LUS consistently outperformed CXR for early detection of perioperative atelectasis and aspiration, with meta-analyses reporting pooled sensitivity of 88–94% and specificity of 86–96% for pneumonia, compared to lower performance of CXR (sensitivity 53–76%, specificity 71–81%).[12-15] In perioperative cohorts, LUS demonstrated sensitivity of up to 98% and specificity of 96% for atelectasis.[18] Its portability and lack of ionizing radiation make it particularly suited to PACU and ICU monitoring.
- Computed tomography (CT): CT retained a central role as the problem-solving tool, distinguishing atelectasis from consolidation, detecting mucus plugs, aspiration syndromes, and complications such as empyema or barotrauma. CT also refines ARDS characterization, with typical patterns of dependent consolidation and nondependent ground-glass opacities.[7,10,20]
- CT pulmonary angiography (CTPA): CTPA remains the cornerstone for suspected PE, with sensitivity of 83–90% and specificity of 94–98% in multidetector-era studies.[21] Importantly, CTPA frequently identifies alternative causes of postoperative hypoxemia (aspiration, pneumonia, atelectasis). V/Q-SPECT remains highly accurate (sensitivity 96%, specificity 97%) when baseline CXR is normal and contrast is contraindicated.[22] Compression ultrasonography provides additional support when thoracic imaging is not feasible (sensitivity ~94%, specificity ~98%).[23]

Collectively, these findings can be operationalized into diagnostic algorithms suitable for integration into PACU/ICU checklists, ensuring timely escalation and minimizing missed or delayed diagnoses.

Strengths and Limitations: Strengths of this review include its perioperative focus, integration of guideline statements with primary research, and the proposal of practical algorithms tailored for anesthetized surgical patients.

Limitations include heterogeneity of perioperative cohorts, variability in reference standards, and reliance on non-randomized evidence. Publication bias and extrapolation from ICU cohorts to perioperative settings (particularly for ARDS and aspiration) may also affect generalizability.

Implications for Clinical Practice

Our findings support institutional adoption of standardized perioperative hypoxemia bundles, pairing CXR with LUS for rapid triage and embedding explicit escalation criteria for CT or CTPA. Radiology–anesthesiology collaboration is essential, particularly in interpreting findings confounded by perioperative physiology (e.g., fluid overload, high FiO_2).[15,16]

Future Research

- Prospective perioperative trials comparing LUS-augmented imaging algorithms vs standard care, with endpoints such as diagnostic delay, ICU length of stay, and mortality.
- Cost-effectiveness analyses of incorporating LUS into routine perioperative checklists.
- Development and validation of AI-assisted LUS interpretation tools to minimize operator dependence.
- Standardized perioperative definitions of imaging criteria for aspiration and atelectasis.

Conclusion

A structured, tiered imaging strategy—LUS and CXR for rapid bedside triage, CT for problem-solving, and CTPA for suspected PE—accelerates diagnosis and guides appropriate therapy for perioperative pulmonary complications are shown in the Figure 2. Adopting such pathways will improve perioperative safety, resource stewardship, and outcome consistency.

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Conflicts of interest

There are no conflicts of interest.

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