

ACR Appropriateness Criteria®

Intensive Care Unit Patients

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Abstract

Chest radiography is the most frequent and primary imaging modality in the intensive care unit (ICU), given its portability, rapid image acquisition, and availability of immediate information on the bedside preview. Due to the severity of underlying disease and frequent need of placement of monitoring devices, ICU patients are very likely to develop complications related to underlying disease process and interventions. Portable chest radiography in the ICU is an essential tool to monitor the disease process and the complications from interventions; however, it is subject to overuse especially in stable patients. Restricting the use of chest radiographs in the ICU to only when indicated has not been shown to cause harm. The emerging role of bedside point-of-care lung ultrasound performed by the clinicians is noted in the recent literature. The bedside lung ultrasound appears promising but needs cautious evaluation in the future to determine its role in ICU patients.

The American College of Radiology Appropriateness Criteria are evidence-based guidelines for specific clinical conditions that are reviewed annually by a multidisciplinary expert panel. The guideline development and revision include an extensive analysis of current medical literature from peer reviewed journals and the application of well-established methodologies (RAND/UCLA Appropriateness Method and Grading of Recommendations Assessment, Development, and Evaluation or GRADE) to rate the appropriateness of imaging and treatment procedures for specific clinical scenarios. In those instances where evidence is lacking or equivocal, expert opinion may supplement the available evidence to recommend imaging or treatment.

Key Words: Appropriateness Criteria, Appropriate Use Criteria, AUC, ICU chest radiograph, ICU CXR, ICU portable CXR, Intensive care unit imaging

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Disclaimer: The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Variant 1. Admission or transfer to intensive care unit. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest portable	Usually Appropriate	⚡
US chest	May Be Appropriate (Disagreement)	○

Variant 2. Stable intensive care unit patient. No change in clinical status. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest portable	May Be Appropriate (Disagreement)	⚡
US chest	Usually Not Appropriate	○

Variant 3. Intensive care unit patient with clinically worsening condition. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest portable	Usually Appropriate	⚡
US chest	May Be Appropriate (Disagreement)	○

Variant 4. Intensive care unit patient following support device placement. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest portable	Usually Appropriate	⚡
US chest	May Be Appropriate (Disagreement)	○

Variant 5. Intensive care unit patient. Post chest tube or mediastinal tube removal. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest portable	May Be Appropriate (Disagreement)	⚡
US chest	Usually Not Appropriate	○

Table 1. Appropriateness category names and definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Table 2. Relative radiation level designations

RRL	Adult Effective Dose Estimate Range (mSv)	Pediatric Effective Dose Estimate Range (mSv)
○	0	0
⊕	<0.1	<0.03
⊕⊕	0.1-1	0.03-0.3
⊕⊕⊕	1-10	0.3-3
⊕⊕⊕⊕	10-30	3-10
⊕⊕⊕⊕⊕	30-100	10-30

Note: Relative radiation level (RRL) assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "varies."

SUMMARY OF LITERATURE REVIEW

Introduction/Background

This publication discusses the utility of chest radiographs and chest ultrasound (US) in the intensive care unit (ICU) setting. The intentions for routine daily portable chest radiographs—patient monitoring; documenting the course of disease for which radiographs are obtained after specific procedures or following insertion of tubes and lines, such as endotracheal, nasogastric (orogastric), and chest tubes; placement of pulmonary artery and central venous catheters (CVCs); and chest tube removal—are addressed.

In a study by Palazzetti et al [1], the authors analyzed the frequency of bedside chest radiographs in the ICU and verified their clinical value by using one of the efficacy indexes—diagnostic efficacy—as defined by the ACR Committee on Efficacy to assess the cost-benefit

ratio associated with radiological imaging. For the purposes of this document, we do not consider cost-effectiveness. The authors concluded that the overall diagnostic efficacy of portable chest radiographs is approximately 85% in 258 consecutive patients (160 men, 98 women; mean age, 58 years) admitted to ICUs and recommended that radiologists should maintain familiarity with the interpretation of this examination. Patient stratification by disease indicated that the diagnostic efficacy was 85% in transplant, 91% in postoperative care after general surgery, 83.89% in respiratory failure, 82% in polytrauma, 91% in postoperative care after neurosurgery, 87% in postoperative care after vascular surgery, 83% in neurological conditions, and 93% in other diseases. There were 192 referring practitioners and 63 radiologists who answered the surveys in a study that substantiates the perceived clinical value of radiologist reports for portable chest radiographs, from the perspective of

referring practitioners [2]. The authors concluded, however, that the strategy implementing standardized structured reports for portable chest radiographs will have to satisfy referring practitioners' needs while optimizing radiologists' efficiency [2].

Special Imaging Considerations

A review of the recent literature has several reports of lung US (LUS), which is a bedside point-of-care clinician-performed US of the lung that does not require a requisition order, formal report, or images stored in the electronic medical record. Although these are included in the discussion of the literature, the rating for recommendation is based only on the US done in the radiology department with a formal report and images in the patient's record.

In a prospective study of 253 LUS examinations performed for unexplained deterioration of arterial blood gases, the management was changed directly as a result of information provided by the LUS in 119 out of 253 cases (47%) [3]. In a study by Phillips and Manning [4], a total of 102 chest radiographs and pocket US examinations were performed in 66 patients in the coronary care unit. The pocket US demonstrated overall good concordance with chest radiographs ranging from 77% for pleural effusion to 92% for pneumonia. Additionally, the pocket US examination appeared to anticipate resolution of pulmonary edema prior to the chest radiographs. Compared with transthoracic echocardiography, pocket US had excellent sensitivity for cardiac findings with values ranging from 85% for left atrial enlargement to 100% for cardiomegaly but had limited specificity of cardiomegaly at just 51% [4].

A meta-analysis that included 10 full-text studies that included 543 patients in evaluating the diagnostic accuracy of chest radiographs, and when concomitantly studied LUS, in comparison with CT as the reference standard, for adult critically ill patients with respiratory symptoms, found that chest radiographs have an overall low sensitivity of 49% (95% confidence interval [CI], 40%-58%) and a good specificity of 92% (CI, 86%-95%). The pooled estimates of sensitivity and specificity of chest radiographs and LUS were compared with CT for each pathology investigated. For lung consolidation, chest radiograph sensitivity and specificity were 22% to 40% and 75% to 100%, respectively, compared with 32% to 100% and 87% to 100%, respectively, for LUS. For pleural effusion or hemothorax, chest radiograph sensitivity and specificity ranged from 34% to 69% and 54% to 100%, respectively, compared with sensitivity of 47% to 100% and specificity of 82% to 100% for LUS.

Chest radiograph for pneumothorax had sensitivity of 40% and specificity of 96%, whereas LUS had sensitivity and specificity of 100% for both. Chest radiograph sensitivity ranged from 42% to 100% and specificity from 82% to 100%, and the LUS sensitivity and specificity were 50% to 95% and 83% to 95%, respectively, for interstitial syndrome. In 7 studies, wherein LUS was also studied, US had an overall sensitivity of 95% (92%-96%) and specificity of 94% (90%-97%). However, the authors noted that although the accuracy of chest radiographs for lung pathology was questioned in this meta-analysis, in certain situations, such as line placement, a chest radiograph is preferred over US. They emphasized the importance of adjusting the choice of diagnostic modality on the individual patient and suggested that all modalities be used in guidance with the clinic (eg, history, laboratory results, and setting) and the ability of the physician to adequately use all the data to construct a diagnosis [5].

Initial Imaging Definition

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

DISCUSSION OF PROCEDURES BY VARIANT

Variant 1: Admission or transfer to intensive care unit. Initial imaging

Radiography Chest Portable. The strategy of ordering daily routine chest radiographs for critically ill and mechanically ventilated patients is slowly changing from daily chest radiographs to on-demand radiographs only. In a study evaluating the practice of chest radiographs in a Dutch ICU by Tolsma et al [6], 61% of the responding ICUs were said to never perform chest radiographs on a routine basis and only 7% of responding ICUs were currently performing daily routine chest radiographs for all patients. In this study, they asked the intensivists to judge the clinical value (therapeutic efficacy) of routine and on-demand chest radiographs and to judge the value of an established radiologic evaluation with a radiologist and asked them to state some indications for routine

chest radiographs. The therapeutic efficacy of routine chest radiographs was between 10% and 20% compared with that between 10% and 60% for on-demand chest radiographs.

In a prospective study by Mets et al [7] and a meta-analysis by Ganapathy et al [8], elimination of daily routine chest radiographs and a restrictive approach with chest radiographs performed to investigate clinical changes among critically ill patients led to a decrease in the total number of chest radiographs obtained per patient per day in the ICU, and, without negative influence on length of stay in the ICU and hospital, a decrease in the readmission rate.

A study from a university hospital in British Columbia, Canada, evaluated their quality improvement initiative to reduce daily chest radiographs in the ICU. The authors observed that education, reminders of appropriate indications, and computerized decision support were effective in decreasing the number of routine chest radiographs in an ICU by 26%. There were no differences between the periods in age, sex, or severity of illness (Acute Physiology and Chronic Health Evaluation [APACHE] II score) of the patients, number of chest CTs, mechanical ventilator days, length of ICU stay, and ICU or hospital mortality [9].

Another study by Tolsma et al [10] with a total of 1,102 consecutive cardiac surgery patients showed that the diagnostic efficacy of chest radiographs for major abnormalities was higher for the postoperative on-demand chest radiographs ($n = 301$; 27%) than for the routine chest radiographs taken the morning after surgery ($n = 801$; 73%) (6.6% versus 2.7%, $P = .004$). They concluded that defining clear indications for selective chest radiographs after cardiac surgery is effective and seems to be safe. This approach can significantly reduce the total number of chest radiographs performed and increase their efficacy.

Current evidence shows that chest radiographs could be forgone after lung resection because on-demand chest radiographs based on clinical monitoring have a better impact on management and have not proved to negatively affect patient outcomes [11].

US Chest. A review of the recent literature includes several reports of LUS, which is a bedside point-of-care clinician-performed US of the lung that does not require a requisition order, formal report, or images stored in the electronic medical record. Although these are included in the discussion of the literature, the rating for recommendation is based only on the US done in the radiology department with a formal report and images in the patient's record.

In a systematic review on the diagnostic accuracy of chest radiographs and partly LUS, compared only with CT as the reference standard in patients admitted primarily to the ICU and with respiratory symptoms, found that chest

radiographs have an overall low sensitivity of 49% (CI, 40%-58%) and a good specificity 92% (CI, 86%-95%). The 7 studies that compared LUS with CT demonstrated that LUS was clearly superior to chest radiography in terms of sensitivity 95% (CI, 92%-96%), with similar specificity 94% (CI, 90%-97%). The overall pooled estimates of sensitivity and specificity of chest radiography and LUS compared with CT for lung consolidation, pleural effusion, pneumothorax, and interstitial pathologies was 95% with LUS, with a specificity equivalent to chest radiographs. They concluded that LUS seemed like a very good alternative because of its bedside availability and fewer downsides over chest radiographs and CT. For the purposes of this document, we do not consider availability.

The authors, however, noted that their results question the current use of chest radiograph as the first-line diagnostic modality for critically ill patients with respiratory symptoms as LUS seems to be a good alternative. Larger trials that compare chest radiograph with LUS not only for accuracy but also for effects on outcome, clinical utility, and ease of implementation are needed [5,12].

In another study of 253 LUS examinations, patient management was changed directly as a result of information provided by the LUS in 119 out of 253 cases (47%) [3]. In 81 cases, the change in patient management involved invasive interventions (chest tube, bronchoscopy, diagnostic thoracentesis/fluid drainage, continuous venous-venous hemofiltration, abdominal decompression, tracheotomy), and in 38 cases, noninvasive interventions (PEEP change/titration, recruitment maneuver, diuretics, physiotherapy, change in bed position, antibiotics initiation/change). In 21%, the LUS revealed findings not suspected by the primary physician (7 cases of pneumothorax, 9 cases of significant pleural effusion, 9 cases of pneumonia, 16 cases of unilateral atelectasis, and 12 cases of diffuse interstitial syndrome). It was concluded that, thoracic US has similar diagnostic accuracy to CT in pleural effusion, consolidation, and pneumothorax [3].

Variant 2: Stable intensive care unit patient. No change in clinical status. Initial imaging

Radiography Chest Portable. Unexpected findings on chest radiographs were noted in <6% of the 2,457 daily routine radiographs that were ordered in 754 consecutive ICU patients in a mixed medical-surgical ICU [13].

In a cross-sectional study of ICUs in hospitals in Saudi Arabia, the daily routine chest radiograph was performed in almost 96.8% of ICU patients. However, a majority of the clinical staff members (73%) thought that this current daily routine chest radiographs protocol in the ICUs should be replaced with the on-demand chest radiographs policy. They

observed that intensivists support the change of the current practice of daily chest radiographs and recommend an on-demand chest radiographs policy likely to be followed in intensive care management [14].

In a survey of Dutch intensivists on the current practice of chest radiography in their departments, only 7% of responding ICUs to the survey were currently performing daily routine chest radiographs for all patients, and 61% of the responding ICUs reported never performing chest radiographs on a routine basis. A daily meeting with a radiologist is an established practice in 72% of the responding ICUs and is judged to be important or even essential by those ICUs. The therapeutic efficacy of routine chest radiographs was assumed by intensivists to be between 10% and 20% compared with 10% and 60% for on-demand chest radiographs. Therapeutic efficacy was defined as the percentage of chest radiograph findings that resulted in a subsequent change in patient management. There was a consensus between intensivists to perform a routine chest radiograph after endotracheal intubation, chest tube placement, or central venous catheterization, and for diagnostic workups for pneumonia, acute respiratory distress syndrome (ARDS), or pneumothorax. The authors also discussed the intensivists' awareness of the limited clinical value of routine chest radiographs that may assume a higher clinical value of chest radiographs due to the value of negative chest radiograph findings, which has not been previously studied. The ability of chest radiograph findings to exclude complications, certain clinical situations, or the need for an intervention probably has a clinical impact that is hard to study [6].

In a systematic review and meta-analysis by Ganapathy et al [8] and Mets et al [7] in cardiothoracic surgery patients in the ICU and the post-ICU did not observe any negative influence of on-demand chest radiographs on length of stay in the ICU and hospital and readmission rate. However, Ganapathy et al [8] observed that CIs were wide and harm was not rigorously assessed. Therefore, they concluded that the safety of abandoning routine chest radiographs in patients admitted to the ICU remains uncertain and mandates further investigation.

Current evidence shows that routine daily chest radiographs are not necessary after lung resection because daily imaging in nonhypoxic patients is unlikely to lead to clinically impactful changes in care [15] and because on-demand chest radiographs based on clinical monitoring have a better impact on management without negatively affecting patient outcomes [11].

US Chest. A review of the recent literature has several reports of LUS, which is a bedside point-of-care clinician-performed US of the lung that does not require a requisition order, formal report, or images stored in the electronic medical record. Although these are included in the discussion of the literature, the rating for recommendation is based

only on the US done in the radiology department with a formal report and images in the patient's record.

The 7 studies that compared LUS with CT demonstrated that LUS was clearly superior to chest radiographs in terms of sensitivity 95% (CI, 92%-96%), with similar specificity 94% (CI, 90%-97%). LUS sensitivity was above 95% for consolidation, pleural effusion, pneumothorax, and interstitial pathologies, with a specificity equivalent to chest radiographs. They concluded that LUS seemed like a very good alternative in these patients also because of its bedside availability and fewer downsides over chest radiographs and CT [5,12]. For the purposes of this document, we do not consider availability.

In another study of 253 LUS examinations, the management was changed directly as a result of information provided by the LUS in 119 out of 253 cases (47%) [3]. In 81 cases, the change in patient management involved invasive interventions, and in 21% of cases, the LUS revealed findings not suspected by the primary physician such as pneumothorax, significant pleural effusion, pneumonia, unilateral atelectasis, and diffuse interstitial syndrome. It was concluded that thoracic US has similar diagnostic accuracy to CT in pleural effusion, consolidation, and pneumothorax [3].

Variant 3: Intensive care unit patient with clinically worsening condition. Initial imaging

Radiography Chest Portable. In a survey of Dutch intensivists, there was a consensus between intensivists to perform a routine chest radiograph after endotracheal intubation, chest tube placement, or CVC as well as for diagnostic workups for pneumonia, ARDS, or pneumothorax [6].

A meta-analysis of 10 full-text studies that include 543 patients used to evaluate the diagnostic accuracy of chest radiographs, and when concomitantly studied with LU, in comparison with the reference standard CT for adult critically ill patients with respiratory symptoms, found that chest radiographs has an overall sensitivity of 49% (95% CI, 40%-58%) and specificity of 92% (86%-95%). US had an overall sensitivity of 95% (92%-96%) and specificity of 94% (90%-97%) [5].

In a prospective, single-blind study of 192 critically ill patients, each patient received a LUS examination, a bedside chest radiograph, followed by a thoracic CT scan searching for pneumothorax, CT of the chest confirmed the diagnosis of pneumothorax in 36 (18.75%) patients of which 31 were diagnosed by thoracic US and chest radiograph detected only 19 cases. Overall, LUS showed a considerably higher sensitivity than bedside chest radiograph (86.1% versus 52.7%). LUS also showed higher negative predictive values

and diagnostic accuracy compared with chest radiograph (96.8% versus 90.1% and 95.3% versus 90.6%, respectively). Chest radiographs had a slightly higher specificity than LUS (99.4% versus 97.4%) as well as higher positive predictive values (95.0% versus 88.6%) [16].

US Chest. A review of the recent literature includes several reports of LUS, which is a bedside point-of-care clinician-performed US of the lung that does not require a requisition order, formal report, or images stored in the electronic medical record. Although these are included in the discussion of the literature, the rating for recommendation is based only on the US performed in the radiology department with a formal report and images in the patient's record.

A meta-analysis showed that the diagnostic accuracy of chest US was higher than supine chest radiographs for detection of pneumothorax. It seems that chest US is superior to chest radiographs in detection of pneumothorax, even after adjusting for possible sources of heterogeneity [5,12,16,17]. LUS is also a valid tool in excluding pneumothoraces after lung biopsy in postlung transplant patients [18].

In a multicenter prospective study of 99 patients with suspected ventilator-associated pneumonia, the diagnostic performance of LUS findings of infection with direct microbiologic examination of endotracheal aspirates showed that LUS had a positive predictive value of 86% to 94% [19,20].

LUS showed better sensitivity and specificity than chest radiography for the diagnosis of pleural effusion and also helped distinguish between different forms of effusions, guide thoracentesis, and insertion of chest tubes [21]. LUS could also monitor the volume of effusion drained to help decide removal of the drainage [21]. Evaluation of the performance of a rapid cardiothoracic US protocol, which combines echocardiographically derived E/e' and LUS, for diagnosing acute heart failure in patients with undifferentiated dyspnea in an emergency department showed that the rapid cardiothoracic US protocol provided excellent accuracy for diagnosing acute heart failure [22].

In a prospective, single-center study in the ICU, pulse oximetry and pulmonary US were found to be useful tools to screen for, or rule out, impaired oxygenation or lung abnormalities consistent with ARDS in underresourced settings in which arterial blood gas testing and chest radiography are not readily available [23].

In a prospective, single-center study, combining SpO₂/FiO₂ with US was found to be a useful tools in screening for, or ruling out, impaired oxygenation or lung abnormalities consistent with ARDS criteria in underresourced settings where arterial blood gas testing and chest radiography are not readily available [23].

Variant 4: Intensive care unit patient following support device placement. Initial imaging

Radiography Chest Portable. Endotracheal Tube Placement. Since 1980, there have been only 9 studies present in the literature [24-32] that evaluate the significance of chest radiography in assessing endotracheal tube placement following insertion. In 5 studies, between 12% and 15% of patients had malpositioned endotracheal tubes, many of which required repositioning. Two studies found 28% and 46% of tubes malpositioned upon insertion, and the single dissenting paper found that only 2% were malpositioned. Two studies compared radiographs with physical examination [24,33]. In both studies, physical examination predicted malpositioned tubes in 3% of patients, whereas the radiographs showed malpositioning in 14% of patients in one study and 28% in the other [24,33]. Kollef et al [34] found that the vast majority of malpositioned tubes were discovered in the first 3 days.

Endotracheal tube repositioning based on measurement at the incisors is inaccurate and the magnitude of the intervention does not correlate with the degree of error. Repositioning of endotracheal tubes based on measurements at the incisors should be abandoned; if not abandoned, follow-up chest radiograph images are recommended [35].

Routine daily imaging of patients with tracheostomy in an ICU provides little clinical utility, and chest radiographs in this population should be performed selectively based on the patient's clinical status. In one study of 761 chest radiographs, only 18 (2.3%) radiographs revealed new complications [36]. All complications were clinically suspected prior to imaging. Only 5 (0.7%) complications resulted in a management change. The most common management changes were a change in antibiotic regimen (0.3%) and ordering of diuretics (0.3%) [36].

Studies evaluating the efficacy of deep learning systems with deep convolutional neural networks were accurate to detect presence versus absence of an endotracheal tube, but deep convolutional neural networks did not perform as well and achieved only reasonable accuracy for differentiating low versus normal positioning of the endotracheal tube [37].

Central Venous Catheter. Eight studies were reviewed regarding CVC [24-26,28-30,32,34]. The majority came to the same conclusion: chest radiographs following catheter insertion are useful, with approximately 10% of the chest radiographs demonstrating malpositioned catheters. Pneumothoraces were present in only a small percentage of patients. Gray et al [24] separated jugular and subclavian catheters. Complications were twice as common with subclavian catheters (17% versus 8%), although unsuspected complications were infrequent.

In a retrospective chart review in a large teaching hospital system, the overall rate of clinically relevant complications detected on chest radiographs following US-guided right internal jugular vein catheterization is exceedingly low. A routine chest radiograph after this common procedure is an unnecessary use of resources and may delay resuscitation of critically ill patients [38].

In 200 central line placements for Whipple procedures, 198 lines were placed in the right internal jugular and 2 were placed in the subclavian [39]. No cases of pneumothorax or hemothorax were identified, and 15.3% of CVCs were improperly positioned. Only one (0.5%) of these was deemed clinically significant and repositioned after the chest radiograph was performed. They concluded that routine chest radiographs consume valuable time and resources and rarely affect management. Selection should be guided by clinical factors [39].

Swan-Ganz Catheter. Previously mentioned studies incorporated the position and potential complications of Swan-Ganz catheter placements shown on chest radiographs obtained immediately postprocedure. The majority of complications, which occur in approximately 10% of catheter insertions, are minor and require catheter repositioning [24,26,29,40]. The pneumothorax rate was approximately 2% [26,40].

Nasogastric Tubes. Radiographs are currently the gold standard for nasogastric tube placement confirmation because they can visualize the course of the nasogastric tube. Between 2005 and 2010, 45% of all cases of harm caused by misplaced nasogastric tubes reported by the National Patient Safety Agency were due to misinterpreted radiographs [41].

US Chest. Endotracheal Tube Placement. Das et al [42] published a systematic review and meta-analysis to definitively answer the question about transtracheal US's accuracy in confirming endotracheal tube placement. Transtracheal US pooled sensitivity and specificity were 98%, respectively, and is a useful tool to confirm endotracheal intubation with an acceptable degree of sensitivity and specificity. It can be used in emergency situations as a preliminary test before final confirmation by capnography [42].

In 57 emergency department patients, US correctly identified 11 out of 12 esophageal intubations for a sensitivity of 92% (95% CI, 62-100), but misidentified 1 esophageal intubation as tracheal. Sonographers correctly identified 43 out of 45 (96%) tracheal intubations for a specificity of 96% (95% CI, 85-99) but misdiagnosed two tracheal intubations as esophageal. They concluded that diaphragm motion in right subcostal US view is an effective adjunct to diagnose endotracheal tube placed in patients undergoing intubation in

emergency department, but the limitation of this study is that they did not confirm the correct place of endotracheal tube by capnometer or chest radiographs [43].

Post Chest Tube Placement. In 17 patients with a total of 21 thoracic tube placements, the thoracic tube was visualized entering the intrathoracic space in 100% of cases and can be distinguished from the pleural line by a characteristic M-mode pattern. This is best visualized with the high-frequency (10-5 MHz) linear transducer [44].

Central Venous Catheter. In a prospective, blinded, observational study of 210 consecutive patients undergoing emergency central venous catheterization, US was compared with chest radiography to verify the correct CVC placement and to identify mechanical complications; there was a high correlation between these two modalities in identifying possible malpositioning of the catheter. However, the less time required to perform US allows earlier use of the catheter for the administration of acute therapies that can be lifesaving for critically ill patients [45].

Several studies demonstrated that LUS can reduce CVC insertion-to-use time and improve patient safety [46-48].

LUS was found to be an effective tool to confirm CVC placement in instances where there is a delay in obtaining a confirmatory chest radiograph. Median point-of-care US and chest radiographs completion were 16 minutes (interquartile range, 10-29) and 32 minutes (interquartile range, 19-45), respectively [49].

However, in another study, contrast-enhanced US detected 11 of the 16 true catheter malpositionings. Contrast-enhanced US showed 2 false right atrium misplacements and 5 falsely correct CVC positions. They concluded that contrast-enhanced US is not a suitable alternative for standard chest radiography in detecting CVC location; however, considering its high sensitivity and acceptable specificity in our study, its usefulness as a triage method for detecting CVC location on a real-time basis in the operating room cannot be ignored [50].

A systematic review and meta-analysis to examine the accuracy of bedside US for confirmation of CVC position and exclusion of pneumothorax compared with chest radiography concluded that LUS is faster than radiography at identifying pneumothorax after CVC insertion. When a CVC malposition exists, bedside US will identify 4 out of every 5 earlier than chest radiography [51].

Swan-Ganz Catheter. There is insufficient data evaluating the placement of pulmonary artery catheter. US may be used to guide insertion of a Swan-Ganz catheter.

Nasogastric Tubes. A pilot study confirmed the high sensitivity of US in the correct positioning of gastric tube in

the adult ICU patient. The US examination seems to be easy and faster when performed by an intensivist with a sonographic training of only 40 hours [52].

A study designed to compare the effectiveness of using auscultation, pH measurements of gastric aspirates, and US as physical examination methods to verify nasogastric tube placement in emergency department patients with low consciousness in 47 patients concluded that US is useful for confirming the results of auscultation after nasogastric tube insertion among patients with low consciousness. When US findings suggest that the nasogastric tube placement is not gastric, additional chest radiographs should be performed [53].

Variant 5: Intensive care unit patient. Post chest tube or mediastinal tube removal. Initial imaging

Radiography Chest Portable. Few studies have been performed to evaluate the efficacy of the initial chest radiograph after the insertion of a chest tube. The 3 available studies show that approximately 10% of tubes are malpositioned [25,28,32].

Sepehripour et al [54] performed a meta-analysis of studies evaluating the utility of standard chest radiographs following chest tube removal. A total of 6 prospective observational and retrospective cohort studies evaluating routine and indication-directed chest radiographs following chest tube removal were reviewed [55-60]. These studies found a low rate of complications, most notably pneumothorax, following chest tube removal, the majority of which were predicted clinically [57,59], and a low rate of tube reinsertion between 0.25% and 4% [56,60].

US Chest. A review of the recent literature has several reports of LUS, which is a bedside point-of-care clinician-performed US of the lung that does not require a requisition order, formal report, or images stored in the electronic medical record. Although these are included in the discussion of the literature, the rating for recommendation is based only on the US done in the radiology department with a formal report and images in the patient's record.

Currently, there is limited literature on the evaluation of US for post chest tube removal.

SUMMARY OF RECOMMENDATIONS

- **Variant 1:** Radiography chest portable is usually appropriate for the initial imaging of patients on admission or transferred to intensive care. The panel did not agree on recommending US chest for patients

in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of US chest is controversial but may be appropriate.

- **Variant 2:** The panel did not agree on recommending radiography chest portable for patients in stable ICU with no change in clinical status. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of radiography chest portable is controversial but may be appropriate.
- **Variant 3:** Radiography chest portable is usually appropriate for the initial imaging of patients in ICU with clinically worsening condition. The panel did not agree on recommending US chest for patients in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of US chest is controversial but may be appropriate.
- **Variant 4:** Radiography chest portable is usually appropriate for the initial imaging of patients in ICU following support device placement. The panel did not agree on recommending US chest for patients in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of US chest is controversial but may be appropriate.
- **Variant 5:** The panel did not agree on recommending radiography chest portable for patients in ICU with post chest tube or mediastinal tube removal. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of radiography chest portable is controversial but may be appropriate.

SUPPORTING DOCUMENTS

The evidence table, literature search, and appendix for this topic are available at <https://acsearch.acr.org/list>. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

RELATIVE RADIATION LEVEL INFORMATION

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different

diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table 2). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [61].

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