Performance of an automated electronic acute lung injury screening system in intensive care unit patients*

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Objective: **Lung protective ventilation reduces mortality in patients with acute lung injury, but underrecognition of acute lung injury has limited its use. We recently validated an automated electronic acute lung injury surveillance system in patients with major trauma in a single intensive care unit. In this study, we assessed the system's performance as a prospective acute lung injury screening tool in a diverse population of intensive care unit patients.**

Design: **Patients were screened prospectively for acute lung injury over 21 wks by the automated system and by an experienced research coordinator who manually screened subjects for enrollment in Acute Respiratory Distress Syndrome Clinical Trials Network (ARDSNet) trials. Performance of the automated system was assessed by comparing its results with the manual screening process. Discordant results were adjudicated blindly by two physician reviewers. In addition, a sensitivity analysis using a range of assumptions was conducted to better estimate the system's performance.**

Setting: **The Hospital of the University of Pennsylvania, an academic medical center and ARDSNet center (1994–2006).**

Patients: **Intubated patients in medical and surgical intensive care units.**

Interventions: **None.**

Measurements and Main Results: **Of 1270 patients screened, 84 were identified with acute lung injury (incidence of 6.6%). The automated screening system had a sensitivity of 97.6% (95% confidence interval, 96.8–98.4%) and a specificity of 97.6% (95% confidence interval, 96.8–98.4%). The manual screening algorithm had a sensitivity of 57.1% (95% confidence interval, 54.5–59.8%) and a specificity of 99.7% (95% confidence interval, 99.4–100%). Sensitivity analysis demonstrated a range for sensitivity of 75.0–97.6% of the automated system under varying assumptions. Under all assumptions, the automated system demonstrated higher sensitivity than and comparable specificity to the manual screening method.**

Conclusions: **An automated electronic system identified patients with acute lung injury with high sensitivity and specificity in diverse intensive care units of a large academic medical center. Further studies are needed to evaluate the effect of automated prompts that such a system can initiate on the use of lung protective ventilation in patients with acute lung injury. (Crit Care Med 2011; 39:98–104)**

KEY WORDS: acute respiratory distress syndrome; acute lung injury; automated alerts; automated screening; electronic screening methods; intensive care; lung protective ventilation; low stretch protocol; mechanical ventilation; mortality

Acute lung injury (ALI) and the acute respiratory distress syndrome are major causes of morbidity, mortality, and cost in intensive care units (ICUs) worldwide. Lung protective ventilation (LPV), using low tidal volumes and alveolar pressures, has been shown to reduce mortality in these patients compared with traditional mechanical ventilation (1, 2). However, the practice of LPV has not been widely adopted (3–6). For example, at our own institution, we found that approximately 60% of patients with ALI did not receive LPV from 2000 to 2002 (7).

One reason for underuse of LPV in eligible patients is underrecognition of ALI (7, 8). We recently demonstrated that an automated electronic system that screened for ALI using laboratory, radiographic, and demographic data from our electronic hospital information systems identified intubated patients with ALI in a cohort of ICU patients with major trauma with 86.8% sensitivity and 89% specificity compared with a reference standard established by two physician reviewers when patients with congestive heart failure (CHF) were excluded (9). Because our prior validation study was performed in a uniform population of patients with major trauma from a single ICU, the results may not have been generalizable to a more diverse population of critically ill patients. The primary purpose of this study was to prospectively assess the performance of our automated electronic ALI screening system in all ICU patients at risk for ALI in our hospital.

METHODS

Setting. This study was performed at the Hospital of the University of Pennsylvania, an academic medical center and one of the National Institutes of Health, National Heart, Lung and Blood Institute Acute Respiratory Distress Network Clinical Trials (ARDSNet) centers from 1994 to 2006. This study protocol was reviewed and approved by the Institutional Review Board of the University of Pennsylvania with a waiver for the requirement of written informed consent from participating subjects or their legally authorized representatives.

***See also p. 209.**

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Table 1. Steps performed in the manual acute lung injury screening algorithm

1	Patient census was obtained from each ICU to identify intubated patients on mechanical ventilation
2	In those patients, oxygenation criteria were assessed by reviewing patients' ABG results available from bedside flow sheets and laboratory information systems
3	Patients with a ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (Pao_2/Fio_2) ≤300 were selected for further evaluation, with the exception of patients requiring Fio_2 <0.50 (described in the Methods section)
4	For all patients meeting oxygenation criteria, radiographic reports for all CXRs done during a time period from 24 hrs before to 24 hrs after the qualifying Pao_2/Fio_2 ratio were reviewed for the presence of bilateral infiltrates that were consistent with pulmonary edema; CXR reports were confirmed as qualifying by one of two ARDSNet physician investigators
5	Cases that met the above criteria were screened for pulmonary artery occlusion pressure ≤18 mm Hg (if available) or no clinical suspicion of left atrial hypertension

ICU, intensive care unit; ABG, arterial blood gas; CXR, chest radiograph.

Patients. Intubated patients in the medical ICU, general surgery ICU, and trauma ICU at our hospital were screened prospectively for ALI from November 2004 through April 2005. Several patient populations were excluded from this study. First, patients with a high probability for CHF were excluded, which included patients in the cardiac care unit on the cardiology service (but not patients in the cardiac care unit who were "overflow" from other noncardiology ICUs) and nontrauma patients in the surgical ICUs in the immediate 48-hr postoperative period. Second, neurosurgical patients were excluded, in whom LPV is often relatively contraindicated as a result of the potential for hypercapnia and associated deleterious effects on intracranial pressures (2). Third, patients with a Fio_2 <0.50 were excluded, because these patients were candidates for an automated ventilator liberation protocol, consistent with international consensus guidelines on ventilator weaning (10).

ALI was defined using the American–European Consensus Conference definition: 1) acute onset of bilateral pulmonary infiltrates on chest radiograph (CXR) that were consistent with pulmonary edema; 2) a ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (Pao_2/Fio_2) ≤300; 3) acute onset; and 4) a pulmonary artery occlusion pressure ≤18 mm Hg, if measured, or no clinical evidence of CHF (11). Although the American-European Consensus Conference definition does not require a patient to be intubated to meet criteria for ALI, only mechanically ventilated intubated patients were included in this study because that was an inclusion criterion for ARDSNet clinical trials and the survival benefits of LPV were demonstrated in this population (1, 2).

Study Design. In this prospective observational study, the primary outcome was identification of patients with ALI. ICU patients were screened for ALI prospectively by the electronic system. Concurrently, ICU patients were also screened manually by the method used routinely in our hospital to screen for ALI for enrollment in ARDSNet clinical trials by an experienced research coordinator (B.B.F.) (Table 1).

The automated system screened patients 24 hrs per day, 7 days per week. The ARDSNet research coordinator, blinded to the cases identified by the automated system, manually collected screening data between 8:00 AM and 12:00 PM every weekday, identified cases that had met criteria since 12:00 PM the previous day, and documented the cases in a case report form. All patients identified by the automated system each day were sent to the ARDSNet research coordinator at 1:00 PM the next day for retrospective review after the research coordinator had finished screening for the day and documented the cases she had identified. This was done to allow the research coordinator the opportunity to review any cases for clinical trial enrollment that were missed using the manual screen. If, on retrospective review, the research coordinator agreed that these cases were consistent with ALI, they were designated as ALI without further adjudication. On weekend days, when the ARDSNet research coordinator did not screen, cases identified by the automated electronic system were presented to the research coordinator on the next Tuesday to allow additional time (Monday morning) for identification of weekend cases using the manual screening algorithm.

Cases in which there were discordant screening results between the two screening methods were adjudicated by two ARDSNet physician investigators (B.D.F., P.N.L.) by primary review of the CXR films, arterial blood gas data, and medical record. Physician reviewers were blinded as to which screening method (automated system or manual algorithm) had identified the case. Cases were classified by the physician reviewers as "definite" if they had an arterial blood gas and CXR consistent with ALI and no comorbidities that could result in an alternative diagnosis, "probable" if there were other comorbidities that could theoretically result in CHF but the clinical picture was consistent with ALI, and "not ALI" if the arterial blood gas and CXR criteria were not met or the picture was not consistent with ALI. Only cases designated as "definite" or "probable" cases by both physician reviewers were considered to be ALI in the final analysis.

All cases identified on a weekend by the electronic system and not identified by the manual method on the preceding Friday or the next Monday were reviewed by adjudicators on both dates to see if the CXR and arterial blood gas results differed sufficiently at the time of screening by the two methods to cause discordance in the case designation. When this was found to be true, the case was excluded to obtain an accurate comparison between the two methods. This could happen, for example, if a patient did not meet criteria on Friday by either screening modality, was identified on Saturday by the system after clinical deterioration, and died before being screened on Monday by the manual method.

The physician investigators did not independently review all the concordant screening results, including concordant positive and negative designations for the presence of ALI, because this would have required an additional 1200 case reviews and was thus beyond the scope of this investigation. Recognizing that this may limit the accuracy of our results, we performed a sensitivity analysis (see subsequently) using varying assumptions to provide a range of estimates for the accuracy of the automated system.

Automated Electronic ALI Screening System. The automated electronic system was designed to detect ALI as previously described (9). In brief, the ASSIST (ALI Selection System to Identify Subjects for Treatment/Trials; © 2008 by The Trustees of the University of Pennsylvania) used laboratory, radiographic, demographic, and surgical information available electronically from the information systems in the University of Pennsylvania Health System (Table 2). The ASSIST initiated a timeline for each patient once criteria for ALI were met and all subsequent data for that patient were recorded in a web-based, password-protected database. Once a case was identified as consistent with ALI, this designation was not affected by subsequent data.

Data Analysis. Cases of ALI included the following subgroups: 1) cases identified independently by both the automated system and manual screening; 2) cases initially identified only by the automated system that were considered to be consistent with ALI on re-review by the ARDSNet research coordinator; and 3) discordant cases adjudicated by both physician reviewers to be definitely or probably consistent with ALI. Negative cases of ALI were defined as 1) subjects that were not identified as ALI by either the automated system or manual screening; and 2) all discordant results that were adjudicated by the physician review process as definitely not a case of ALI. Using this

Table 2. Steps performed by the automated electronic system for acute lung injury screening (9)

1	The ASSIST first identified intubated patients either through detection of an electronic order placed by clinicians for a "vented ABG," which designates intubation status, or by recognition of the words "ETT," "endotracheal tube," or "tracheostomy tube" in the radiology report text
2	For all intubated patients, the system then collected ABG results every 6 hrs, calculated a Pao_2/Fio_2 ratio for each ABG, and screened for a qualifying Pao_2/Fio_2 ratio ($\leq$300) with a $Fio_2 \geq 0.5$
3	CXR reports of intubated patients were also screened every 3 hrs using a free-text processing system, and reports were flagged if any of a number of preselected words that denoted bilaterality were detected in the same sentence as any of a number of preselected words synonymous with infiltrates
4	For all intubated patients, the system was programmed to screen for ALI by identifying both a qualifying Pao_2/Fio_2 ratio and CXR report within a rolling 24-hr time interval
5	When the first such interval that met criteria for ALI was detected, regardless of which criterion was met first, the system stored these data automatically in real time in a password-protected web site and notified the research coordinator of the result by sending an electronic alert through e-mail after a specified period of time to allow her to find the case

ASSIST, Acute Lung Injury Selection System to Identify Subjects for Treatment/Trials; ABG, arterial blood gas; ETT, endotracheal tube; CXR, chest radiograph; ALI, acute lung injury.

classification system, we calculated the sensitivity, specificity, and positive and negative predictive values of the automated electronic system and the manual screening method. Results were expressed as proportions with 95% confidence intervals (CIs). The study was powered to evaluate an estimated sensitivity of 95% such that the lower bound of the CI did not include 93%. Using the modified Wald method, we calculated that a sample size of 1000 would allow us to obtain 95% CIs that range from 93.5% to 96.2% around an estimated 95% sensitivity (12). Calculations were done in Excel (Microsoft Inc, Redmond, WA), and 95% CIs were calculated using R.

A sensitivity analysis was conducted to determine estimates for the performance parameters of the two screening methods under a range of assumptions about the nonadjudicated cases. The upper limit of the range for sensitivity assumed that there were no cases misclassified by both methods as positive, and the upper limit of the range for specificity assumed that there were no cases misclassified by both methods as negative. The lower limits of these ranges were derived from estimates of the maximum number of cases that could have been either missed or falsely identified by both methods; these estimates were based on an incidence of ALI in the United States of 0.7–5.8 cases of ALI per ICU bed per year (13).

RESULTS

During a 21-wk period from November 2004 through April 2005, 1297 intubated ICU patients who occupied approximately 40 ICU beds were screened independently by the automated electronic system and the manual screening algorithm (Fig. 1). A total of 46 cases of ALI were identified by both the automated system and the manual algorithm, seven cases were identified by the manual algorithm alone, 90 cases were identified by the automated system alone, and 1154 were not identified as ALI by either screening method.

All cases identified by only one screening modality were adjudicated. Of the 90 cases identified by the automated system alone, 25 patients were excluded from further review because they were not in an ICU location screened by the research coordinator (overflow patients in the cardiothoracic ICU or cardiac care unit) (n = 16), the medical record could not be retrieved to enable case adjudication (n = 4), or because discordance was the result of identification on the weekend (n = 5). Of the remaining 65 cases, 21 cases were found to be consistent with ALI on retrospective review by the research coordinator using her method for manual screening and 44 cases were adjudicated by the physician reviewers. Fifteen of the 44 adjudicated cases were found to be consistent with ALI and 29 were found not to be consistent with ALI. Of these 29, 21 were found to be consistent with either CHF or atelectasis rather than ALI. Eight were found to have been incorrectly selected as a result of identification of qualifying phrases in the radiology report text, although the context of the phrase was not consistent with ALI (eg, the words "endotracheal tube" were detected in the phrase, "endotracheal tube has been removed").

The manual screening algorithm identified seven additional patients who were not identified by the automated system. Of these, two were excluded because they were identified within 48 hrs of surgery (a predetermined exclusion criterion), two cases were adjudicated as consistent with ALI, and three cases were adjudicated as not consistent with ALI (Fig. 1).

We calculated the total number of cases of ALI during this time period to be 84, the sum of the cases in the shaded boxes in Figure 1. Thus, using these 84 cases as the reference standard, the incidence of ALI in the study population was 6.6% (84 of 1270) (95% CI, 5.3–8.2%) or 5.2 cases of ALI per ICU bed per year. Using the cases identified by the selection process in Figure 1 as the reference standard, the manual method identified 48 of the 84 true-positive cases as ALI (46 + two) and correctly identified 1183 (29 + 1154) of 1186 negative cases as such; therefore, there were 36 false-negative and three false-positive cases. The ASSIST identified 82 (46 + 21 + 15) of 84 true-positive cases of ALI and correctly identified 1157 (1154 + three) of 1186 negative cases as such; therefore, there were two false-negative and 29 false-positive cases. Performance parameters for both screening methods are listed in Table 3.

Sensitivity analysis of the sensitivity and specificity of the two screening methods was conducted using an estimate of the total number of expected ALI cases in a 21-wk period in 40 ICU beds of between 11 and 94 cases (13). Because 84 total cases of ALI were identified in this study, a maximum of ten additional cases was estimated to have been falsely missed by both screening methods (ie, ten of the 1154 nonadjudicated cases not identified as ALI by either system in Fig. 1). This was the first parameter varied in the sensitivity analysis; thus, the sensitivity and specificity of the two screening methods were calculated as the number of cases misclassified by both methods as negative was varied from zero to ten (on the abscissa in Figs. 2 and 3). The minimum number of ALI cases during this time was predicted by Goss et al to be 11 (already exceeded by the 38 cases adjudicated to be consistent with ALI by the physician reviewers). This was therefore the second parameter varied in the analysis with the lower bounds of the sensitivity and specificity calculated under the assumption that all of the 46 cases found to be consistent with ALI by both methods (and therefore not adjudicated in the study) would have been negative for ALI if they had been adjudicated by physician reviewers (Figs. 2 and 3).

The ASSIST demonstrated a higher sensitivity range than the manual method under all assumptions, ie, under the assump-

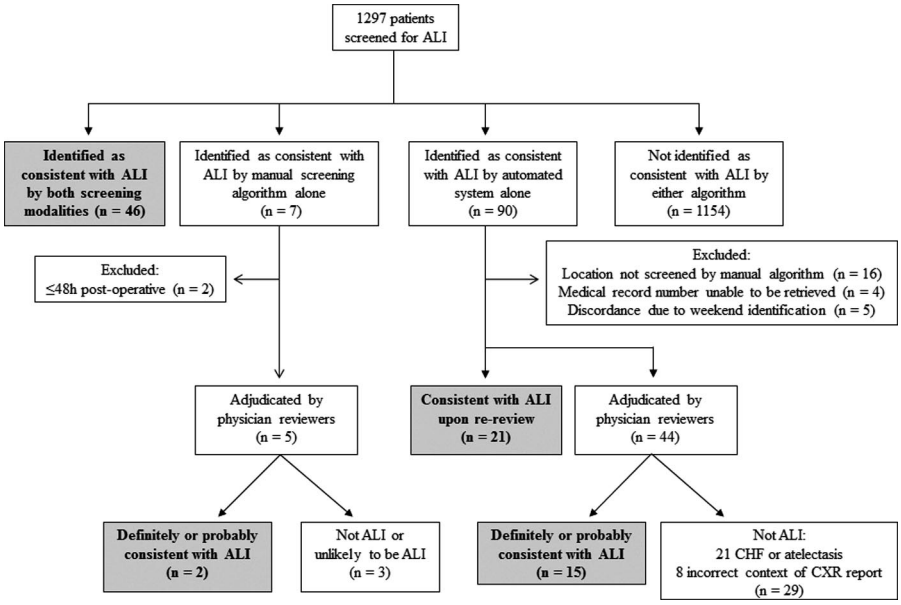

Figure 1. Flow diagram of study results. Cases in shaded boxes were added to obtain the number of cases of acute lung injury (*ALI*) for the analysis. *CHF*, congestive heart failure; *CXR*, chest radiograph.

Table 3. Performance parameters (with 95% confidence intervals) of the ASSIST and the manual screening algorithm in identifying ALI relative to the two-step reference standard

	Sensitivity	Specificity	PPV	NPV
ASSIST	97.6% (96.8–98.4%)	97.6% (96.8–98.4%)	73.9% (71.5–76.0%)	99.8% (99.5–100%)
Established manual screening algorithm	57.1% (54.5–59.8%)	99.7% (99.4–100%)	94.1% (92.8–95.4%)	97.0% (96.1–97.9%)

ALI, acute lung injury; ASSIST, Acute Lung Injury Selection System to Identify Subjects for Treatment/Trials; PPV, positive predictive value; NPV, negative predictive value.

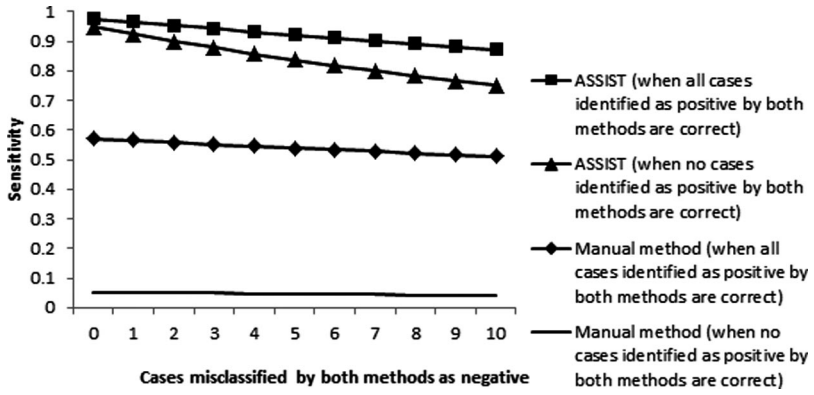

Figure 2. Range of sensitivity of the Acute Lung Injury Selection System to Identify Subjects for Treatment/Trials (*ASSIST*) compared with the manual screening method. Parameters varied were 0–10 cases of the 1154 cases potentially misclassified as negative by both methods as depicted in Figure 1 (x-axis) and 0–46 cases potentially misclassified as positive by both methods (*squares* vs. *triangles* for the ASSIST, *diamonds* vs. *straight line* for the manual method). The ASSIST demonstrated a higher sensitivity range than the manual method under all assumptions.

tion that all 46 cases identified by both methods as consistent with ALI were correct (ASSIST, 87.2–97.6%; manual method, 51.1–57.1%) and under the assumption that all 46 of these cases were not actually consistent with ALI (ASSIST, 75.0–94.7%; manual method, 4.2–5.3%) (Fig. 2). The ASSIST was estimated to have a slightly lower range of specificity than the manual screening method under the same range of assumptions, although the specificity of either method never fell below 97.5% (Fig. 3).

DISCUSSION

An automated electronic system identified cases of ALI in patients admitted to diverse ICUs of an academic medical center with a high degree of sensitivity and specificity, when compared with a manual screening method, from November 2004 to April 2005. These results extend prior observations that initially validated this automated ALI screening system in a more homogeneous population of major trauma patients in a single ICU from October 2005 to April 2007.

Ultimately, the clinical value of this system will be judged by whether it can increase the use of LPV in patients with ALI through an automated prompt. Of note, some have argued that all mechanically ventilated patients should be placed on LPV, regardless of the presence of ALI, to reduce ventilator-induced lung injury, which would obviate the need for an ALI alert system. This notion originates from observational studies, which showed that patients who were ventilated with a lower tidal volume had a decreased risk of developing ALI. However, at present, there are no prospective observational or interventional studies to support this approach and, thus, it has not been embraced in most institutions (14, 15). Furthermore, should additional ventilation strategies or treatment modalities prove useful in reducing morbidity or mortality in patients with ALI in the future, this system can be readily adapted to promote their use.

This system worked independently from the treating physicians, which is critical for diagnosing underrecognized clinical events (16). There is considerable interobserver variability in the interpretation of CXRs among critical care physicians (17) as well as radiologists, whose impressions likely influence clinician thinking. The CXR cannot reliably distinguish CHF from ALI (18). Notably, the radiographic criteria for ALI used by the ARDSNet in their landmark clinical trial of LPV showed a mortality benefit in patients with bilateral pulmonary infiltrates of any type, including interstitial or patchy, or extent as long as the ARDSNet investigators judged them to be consistent with pulmonary edema and not the result of atelectasis or pleural effusions (1, 2). We speculate that radiologists' interpretations of CXR findings as consistent with processes other than ALI (eg, CHF or atelectasis) may have influenced the manual screening process in this

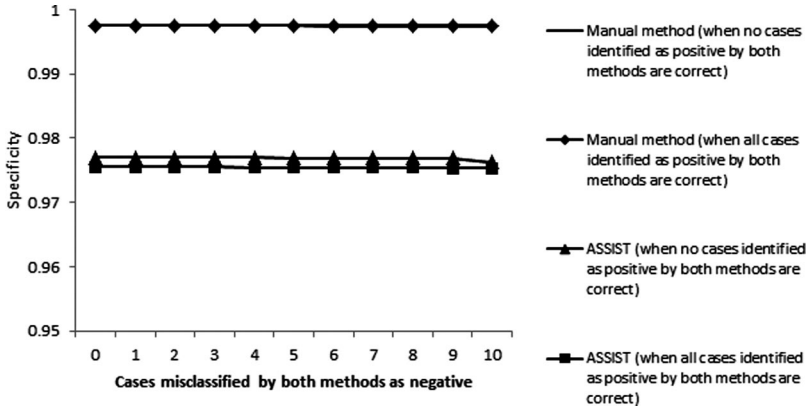

Figure 3. Range of specificity of the Acute Lung Injury Selection System to Identify Subjects for Treatment/Trials (*ASSIST*) compared with the manual screening method. Parameters varied were 0–10 cases of the 1154 cases potentially misclassified as negative by both methods as depicted in Figure 1 (x-axis) and 0–46 cases potentially misclassified as positive by both methods (*squares* vs. *triangles* for the ASSIST, *diamonds* vs. *straight line* for the manual method). The ASSIST demonstrated a slightly lower specificity range than the manual method under all assumptions, although specificity for the ASSIST did not fall below 97.5%. Notes: y-axis ranges from 95% to 100%; the two lines depicting the manual method specificity ranges overlap (*diamonds* and *straight line*).

study and could have resulted in missed cases of ALI. By adhering to the American-European Consensus Conference definition of ALI, the automated electronic system may avoid some of the commonly encountered biases that can delay the diagnosis of ALI such as misinterpretation of a CXR as CHF rather than ALI (17) or assumption that lung disease does not appear to be severe enough to be consistent with ALI (1, 2) by identifying phrases in the radiology report that indicate the presence of bilateral infiltrates regardless of the extent of disease or the radiologist's overall diagnostic impression.

Given its higher sensitivity and slightly lower specificity relative to the manual method, the ASSIST may prove most useful as a screening and alert tool rather than a diagnostic tool. The importance of developing systems to enhance delivery of beneficial therapies to patients is becoming increasingly evident (19–21). A systematic review showed that computerized reminders increase the probability of providing correct care by 420% (22). Pilot studies have recently demonstrated the feasibility of electronic diagnostic tools for respiratory conditions associated with ALI in ICU patients such as ventilator-associated pneumonia and transfusion-related acute lung injury (16, 23). Our fully automated system not only identified ALI using multiple integrated information systems for hospitalized ICU patients at risk for ALI, but also appeared to be unique and effective in its ability to detect intubation status using a combination of CXR and laboratory data. Given the multiple handoffs between residents that occur in academic centers as work hour regulations evolve, automated systems that reliably and consistently screen critically ill patient populations for disorders that have effective treatments may improve outcomes. However, before this tool is applied in the clinical setting, additional improvements that may decrease potentially harmful interruptions in workflow as a result of false-positive or unnecessary alerts warrant consideration. For example, with increasing deployment of electronic medical records, there will be an opportunity to include in our screen a search for ALI risk factors documented in physicians' notes. In addition, hemodynamic measurements as well as electrocardiographic and echocardiographic interpretations could potentially be included to further decrease false-positive cases with CHF. Furthermore, unnecessary prompts (ie, when providers are already using LPV in appropriate patients) could be reduced by automatically assessing data on current ventilator orders or settings.

A recent study by Herasevich et al (20) reported on an electronic "ALI sniffer" system that used arterial blood gas and free-text radiologic interpretation to diagnose ALI with 96% sensitivity (95% CI, 94–98%) and 89% specificity (95% CI, 88–90%). Our system's positive predictive value was 73.9% (95% CI, 71.5–76.3%) compared with the "ALI sniffer's" positive predictive value of 46% (95% CI, 42.2–49.9%), which may be attributable in part to our system's free-text CXR query that was able to detect a variety of complex words and phrases that suggested the presence of bilateral infiltrates (9). Natural language processing may further improve the system's performance (9). The success of automated electronic ALI detection systems in two different geographic and clinical settings suggests that electronic surveillance tools are feasible and effective in diverse ICU patient populations and institutions.

This electronic system represents an attractive alternative to manual screening of ICU patients for enrollment into ALI research studies (or other research in respiratory failure). Once integrated into the hospital's information system, the automated system may result in substantial savings in screening time and effort. It may also be more effective at finding eligible patients as a result of its high sensitivity; in this study, the automated system identified 36 cases ultimately found to be consistent with ALI that were not initially identified by the manual screening method. In addition, our system screened continuously throughout the day and night as well as on the weekends.

There are several limitations to our study. First, our results are potentially prone to classification bias because of the way we defined the number of ALI cases and because the 46 cases identified as positive and the 1154 cases deemed negative for ALI by both screening methods were not adjudicated. However, in contrast to the study by Herasevich et al in which the "ALI sniffer" was the only screening method used and physician reviewers who verified case status were not blinded to the case designation by the "sniffer," this study's use of an established manual screening algorithm to independently identify cases of ALI concurrently with the automated system reduced the potential for selection bias. This methodology also allowed a more accurate estimate of sensitivity (because two cases were identified by the manual method that were not identified by the ASSIST) while at the same time having all discrepant cases adjudicated by blinded objective expert reviewers. In addition, the sensitivity analysis demonstrated that the ASSIST performed well under a range of assumptions about the nonadjudicated cases. Thus, we believe the analysis performed in this investigation should represent a reasonable estimate of the system's performance.

Second, this system was compared with the manual screening method

used by a single ARDSNet research coordinator (although all CXRs for patients enrolled by the research coordinator were confirmed by an ARDSNet physician investigator). Despite her use of a standardized protocol, it is possible that the results of this study could have been affected by her individual screening practices (eg, not screening on nights or weekends, screening CXR reports each morning that were done the previous day rather than being directly alerted by the radiologist, etc). However, several steps were taken to obtain an accurate comparison despite the differences in screening times, as described in the Methods section. In addition, although comparison of the ASSIST with the current manual screening method at our institution is useful, it should be noted that the ASSIST performed with 97.6% sensitivity and specificity relative to a two-step reference standard that included a blinded adjudication process.

Third, our system may not be generalizable to other hospitals, because it was developed using integrated information systems that may be unique to our institution and the CXR query was developed using words and phrases that may be unique to the radiologists in our hospital. However, radiologists across institutions appear to demonstrate remarkable consistency in their descriptions of ALI (20). As electronic medical record systems are improved and expanded, this study demonstrates feasibility and a potential model for the development of similar systems in other institutions to improve quality of care and reduce errors.

Finally, the ASSIST is not able to use the fourth parameter of the American-European Consensus Conference definition of ALI (pulmonary artery occlusion pressure $\leq$18 mm Hg or no clinical suspicion of left atrial hypertension) because hemodynamic measurements and physician documentation are not recorded in an electronic database accessible to the ASSIST. To compensate for this deficiency, so as to minimize false-positive (nuisance) alerts such as those for patients who have CHF, we incorporated rules into ASSIST to reduce the likelihood of selecting patients who fail to meet the CHF exclusion criteria. As such, we excluded patients residing in the cardiac care unit on the cardiology services and nontrauma surgical patients during their immediate 48-hr postoperative period. These rules were based, in part, on prior assessments of the reasons physicians refused to enroll screened patients into ALI research trials (data not shown). Nevertheless, we acknowledge that this approach may miss opportunities to diagnose ALI in some patients in these groups. Should it become possible to more accurately differentiate ALI from CHF, we may be able to identify these lost opportunities without increasing the false-positive rate. Additional studies are needed to further evaluate the system's specificity, its generalizability, and most importantly the effect of automated prompts on the use of LPV and on mortality in patients with ALI.

CONCLUSIONS

This study demonstrated that this electronic screening system (ASSIST) has the potential for broad, real-world applicability as a sensitive and specific automated screening tool for ALI in ICU patients. As such, this system may potentially be used to promote early initiation of appropriate therapy (LPV) for critically ill patients with ALI to improve the delivery of care. In addition, it may also be useful to screen patients for enrollment into research trials and to provide a metric and data collection system for assessing hospital quality improvement measures for patients with acute hypoxemic respiratory failure.

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