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Clinician recognition of the acute respiratory distress syndrome: Risk factors for under-recognition and trends over time

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Abstract

Objective: The acute respiratory distress syndrome (ARDS) is common in critically ill patients. Recognition is crucial because ARDS is associated with a high mortality rate, and low tidal volume ventilation (LTVV) improves mortality. However, ARDS often goes unrecognized. Risk factors for under-recognition and trends over time have not been fully described.

Design: Retrospective chart review of patients with ARDS from a prospective cohort study of critically ill patients. For each patient's intensive care unit stay, we searched the chart for terms that indicated that ARDS was diagnosed, in the differential diagnosis, or treated with LTVV.

Setting: Intensive care units at a tertiary hospital at the University of California, San Francisco (UCSF) between 2008 and 2016.

Patients: Critically ill patients with ARDS.

Interventions: None.

Measurements and Main Results: ARDS was recognized in 70% of patients, and recognition increased from 60% in 2008–2009 to 92% in 2016 ($p = 0.004$). Use of tidal volumes less than 6.5 mL/kg also increased ($p < 0.001$) from 20% to 92%. Increased ARDS severity ($p = 0.01$) and

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vasopressor use (p = 0.04) were associated with greater recognition. Clinician diagnosis of ARDS and inclusion of ARDS in the differential diagnosis were associated with tidal volumes less than 6.5 mL/kg (51% use of tidal volume ≤ 6.5 ml/kg if ARDS recognized vs. 15% if not recognized, p = 0.002). Diagnosing ARDS was associated with lower tidal volume in multivariate analysis.

Conclusions: Although ARDS recognition and LTVV use have increased over time, they remain less than universal. Clinician recognition of ARDS is associated with both systemic and respiratory severity of illness and is also associated with use of LTVV.

Keywords

Acute respiratory distress syndrome; diagnosis; critical care; electronic health record; documentation; risk factors

Introduction

The acute respiratory distress syndrome (ARDS) affects approximately 10% of adult intensive care unit patients worldwide (1). Characterized by acute inflammatory lung injury and hypoxemic respiratory failure, it has an in-hospital mortality of 40% (1). Low tidal volume ventilation (LTVV) improves survival (2) and is the recommended treatment for ARDS (3).

However, LTVV is under-utilized. In a study of Chicago area hospitals, only 19% of ARDS patients had tidal volumes (TVs) less than 6.5 mL/kg at any time during mechanical ventilation (4), and only 27% of patients in a University of Washington study received low TVs within 48 hours of diagnosis (5). In a large international study of ARDS epidemiology by Bellani et al., 35% of patients with ARDS received TV > 8 mL/kg. This under-utilization is likely in part because ARDS often goes unrecognized, although this link has been challenged recently (6). Estimates of ARDS recognition based on medical record review vary from 12.4% to 60.2% (1, 4, 5, 7–9). These differences in estimates of ARDS recognition could reflect variable methods for measuring recognition, variability between institutions, or a trend of increased recognition over time.

The reasons for ARDS under-recognition are not well understood. Possible contributing factors include the low specificity of the consensus diagnostic criteria and variable chest radiograph interpretation (6). Patient, clinician, and institutional factors may also contribute. Bellani et al. found that higher nurse- and physician-to-patient ratios, younger patient age, the presence of pneumonia or pancreatitis, and lower Pa_{O_2}/F_{IO_2} ratios were associated with increased recognition (1). Another study showed that provider disagreement regarding ARDS diagnosis was associated with reduced severity of hypoxemia (10). These factors, though, may differ among institutions or change over time.

Our primary objective was to determine the rate of clinical recognition of ARDS at our tertiary care hospital, which has been a part of the National Heart, Lung, and Blood Institute (NHLBI) ARDS Clinical Trials Network for over 20 years (2) and is now part of the NHLBI Prevention and Early Treatment of Acute Lung Injury (PETAL) network. We also aimed to identify patient and provider factors associated with recognition. Using a prospectively

identified cohort of patients with ARDS admitted to a single center, we retrospectively reviewed their electronic health records for evidence of ARDS recognition. We hypothesized that ARDS recognition has increased over time, that ARDS is more frequently recognized in patients with greater hypoxemia and illness severity, and that ARDS recognition is associated with LTVV use.

Materials and Methods

Patient selection

Patients for this study were enrolled as part of the Early Assessment of Renal and Lung Injury (EARLI) study, an ongoing prospective cohort of adult patients (18 years or older) with critical illness. Patients were eligible for inclusion in EARLI if they were admitted via the emergency department to the intensive care unit (ICU), and Supplementary figure 1 and the Supplementary Methods describe reasons for exclusion. The study was approved by the Institutional Review Board of the University of California, San Francisco (UCSF). Informed consent was obtained for all patients, except when the IRB approved a waiver. This waiver applied to 1) patients who died before consent could be obtained and 2) patients whose critical illness precluded providing informed consent and for whom no surrogate was identified within 28 days of admission.

Participants in this study were enrolled in EARLI at the UCSF Moffitt-Long Hospital from October 2008 to October 2016, and from these patients, we selected those with ARDS, as defined by the Berlin criteria (11). Specifically, patients had to have bilateral pulmonary infiltrates unexplained by cardiac failure or volume overload and a Pa_{O_2}/F_{IO_2} ratio ≤ 300 in the setting of a known clinical insult. ARDS determination was made by two critical care specialists (CC and MAM) who reviewed all chest imaging, elements of the patient's clinical course and history, and recent echocardiograms. All of these elements of data were also available to treating clinicians during the patient's hospitalization. The two critical care specialists then independently determined whether imaging findings could be explained by volume overload/heart failure alone, lung injury alone, or a mixture of both etiologies. To handle disagreement about diagnosis for a case, the two specialists met and discussed the case until consensus was reached. Patients with either lung injury alone or a mixed etiology were included in our study. We also limited our study to intubated patients, excluding patients who only required non-invasive positive pressure ventilation (NIPPV), because we intended to analyze mechanical ventilation patterns. In a separate analysis of TV trends, we also analyzed data from all patients over this same time period who did not meet Berlin ARDS criteria but were both intubated and had a PaO_2/FIO_2 ratio ≤ 300.

ARDS recognition

To identify clinician recognition of ARDS, we systematically reviewed each patient's medical record for terms that suggested providers diagnosed ARDS, considered ARDS in the differential diagnosis, or discussed the use of LTVV. These terms included multiple ways to document ARDS and LTVV, such as "low tidal" (Supplementary table 1).

At the UCSF Moffitt-Long hospital, all ICU patients have an ICU team that manages ventilation, sedation, and IV access and consults on issues related to critical illness. Most of these ICU patients also have a primary team that provides other care for the patient during the ICU stay and cares for the patient during the rest of the hospitalization. Both types of teams have an attending and either a resident or nurse practitioner (NP). When searching for ARDS recognition, we included all progress notes and admission notes written by the primary and ICU residents, NPs, and attendings while the patient was in the ICU. We also searched discharge summaries if the service date was during the ICU stay.

We reviewed patient charts in two phases. In both phases, we searched for the nine terms in Supplementary table 1. For records prior to June 2012, a study investigator read each chart and manually searched for ARDS terms while also confirming the completeness of the terms used to identify ARDS recognition. In early June 2012, the electronic medical record (EMR) changed, and charts could be more easily downloaded and searched, so after that, a specialized interface (Programmer's Notepad v2.3, Simon Steele) was used to identify ARDS recognition (see Supplementary Methods). Each line that contained a character string suggestive of recognition was manually reviewed to ensure that providers recognized ARDS. The investigators who reviewed each line also decided based on context in the note whether the providers diagnosed ARDS, included it in the differential diagnosis, and/or used LTVV.

Patient and provider covariates

We analyzed several patient and provider factors for association with ARDS recognition. These included patient race, ARDS risk factors, medical comorbidities, provider specialty, ventilator settings, and measures reflecting illness severity (Table 1, Supplementary Methods). We also analyzed the year during which the patient received care because with education efforts and changes in provider workflow, such as making LTVV the default ventilator protocol in 2016, ARDS recognition may have increased with time. ARDS was mild if Pa_{O_2}/F_{IO_2} ratio ≥ 201, moderate if 101 ≤ Pa_{O_2}/F_{IO_2} ≤ 200, and severe if Pa_{O_2}/F_{IO_2} ≤ 100. The Murray Lung Injury Score was calculated as described previously (12).

We also explored whether recognition was associated with TVs and mortality. TV and other ventilator settings were measured daily at 8 AM, except for Pa_{O_2}/F_{IO_2}, for which the lowest value of the day was used. TV was measured in mL/kg, where ideal body weight was calculated using the Devine formula (13), as previously used (2). When analyzing TV, we used the minimum TV between day 0 and day 1 of when a patient both met ARDS criteria and was intubated; TVs analyzed included those generated by patient effort, such as with pressure support ventilation (PSV). However, only six patients were documented as receiving PSV and no other mode on days 0 and 1 of ARDS. For mortality data, patients were either followed until hospital discharge or 60 days, whichever came first.

Statistical analyses

All statistical analyses were performed using R version 3.3.2, and code is available on request. We analyzed the association between ARDS recognition and categorical variables using a chi-squared test with the Yates' continuity correction, except that we used Fisher's exact test if any cell in a contingency table was less than 5. To directly compare two

proportions, we used the z-proportions test. For association between ARDS recognition and continuous variables, we used either Welch's *t*-test assuming unequal variance or, for skewed variables, the Wilcoxon rank-sum test. We used multivariable linear regression to determine whether accurately diagnosing ARDS (ARDS being both diagnosed in the medical record and present) was associated with TV. To do this, we also combined our original cohort with additional hypoxic patients ($Pa_{O_2}/F_{I_{O_2}} < 300$) that did not meet ARDS criteria, and we adjusted for year and whether ARDS was present. To identify independent factors associated with recognition, we used multivariable logistic regression, focusing on covariates that were significantly ($p < 0.05$) associated with recognition in univariate analysis. In a sensitivity analysis, we also adjusted for other factors previously associated with recognition (1). Finally, we did a multivariable logistic regression with recognition predicting mortality, adjusting for variables that could potentially explain both mortality and recognition. For each analysis, we used all available data without imputation.

Results

Over the study period, 985 patients were admitted to the Moffitt-Long ICU and enrolled in the EARLI study, and of these, 141 were both intubated and determined by study investigators to meet Berlin criteria for ARDS. Of these patients, 29% were felt to have pulmonary edema secondary to both lung injury and volume overload, and the remainder had pulmonary edema secondary only to lung injury. The two study investigators establishing ARDS diagnosis independently agreed on the number of chest x-ray quadrants involved for 97% of patients and on whether there were bilateral infiltrates for 99% of patients.

Clinicians recognized ARDS in 70% of these 141 patients. ARDS was either diagnosed or in the differential diagnosis for 60% of patients, and ARDS was specifically diagnosed for 50%. LTVV use was documented for 60% of patients (Figure 1A), most of whom also had documentation of ARDS diagnosis (Figure 1B). Among patients for whom ARDS was recognized, 8% had ARDS recognized at least two days after ARDS criteria were met, and for 16%, clinician documentation preceded ARDS criteria being met (Supplementary figure 2).

ARDS recognition significantly increased over time (Figure 2A, logistic regression $p = 0.005$ for recognition vs. year), while average TV decreased (Figure 2B, $p < 0.0001$). ARDS was recognized for 60% of patients in 2008–2009 but 92% in 2016. Patients' minimum TVs between day 0 and 1 of ARDS criteria and intubation had a mean of 8.1 mL/kg in 2008–2009 compared to 6.0 mL/kg in 2016, with 20% and 92%, respectively, having TVs less than 6.5 mL/kg. In 2016, the default order set for mechanical ventilation became LTVV. After excluding patients from 2016, the associations between recognition and TV, recognition and year, and TV and year remained significant ($p = 0.004$, 0.02, and 0.0006, respectively).

The ICU team recognized ARDS more frequently than the primary team (67% vs. 55%, $p = 0.051$, Supplementary figure 3A), partly because the ICU team more often documented LTVV (59% vs. 40%, $p = 0.002$). The ICU and primary teams had similar rates of diagnosing ARDS or including ARDS in the differential diagnosis (53% vs. 48%, $p = 0.47$).

Recognition differed among specialties (p = 0.0079), with recognition least likely on the cardiology or cardiothoracic surgery services (Table 1, p = 0.0078 for cardiology and cardiothoracic surgery vs. other).

Several patient demographic and clinical variables were associated with ARDS recognition (Table 1), including acute kidney injury (AKI), greater net fluid balance in the first 24 hours, and the presence of sepsis. Other variables approached significance, such as race ($p < 0.1$), with African-American patients under-recognized compared to others (p = 0.035). Notably, whether the patient had cardiac disease and whether cardiac failure was thought to have contributed to pulmonary edema were not associated with recognition (Table 1).

Several variables related to illness severity and ventilation were also associated with ARDS recognition in univariate analysis (Table 2). These included vasopressor use (p = 0.04), ARDS severity (Chi-square test overall p = 0.012, Chi-square test for severe ARDS vs. mild or moderate p = 0.054), and the Lung Injury Score (p = 0.015). The association between ARDS severity and recognition was non-linear, with mild ARDS recognized more often than moderate cases (Table 2). Compared to when ARDS was unrecognized, patients for whom ARDS was diagnosed or in the differential diagnosis were more likely to have TV less than 6.5 mL/kg (51% vs. 15%, p = 0.0008, Figure 3B) or TV less than 8 mL/kg (82% vs. 58%, p = 0.008, Figure 3C).

Because the link between ARDS recognition and LTVV use was recently challenged (6), we also explored whether these variables' association was explained by confounders, particularly the trend of increased LTVV use over time. We extracted data from the EARLI cohort for the 124 additional patients who did not meet Berlin ARDS criteria but were both intubated and had a Pa_{O_2}/F_{IO_2} ratio ≤ 300. Compared to ARDS patients, the non-ARDS patients' TVs were less than 6.5 mL/kg less often (24% vs. 40%, chi-squared p = 0.016), but TV decreased for both the ARDS and non-ARDS patients by on average 0.22 mL/kg and 0.29 mL/kg per year, respectively ($p < 0.0001$ for each association with year). Recognition data was unavailable for the non-ARDS patients, so for a combined analysis of both our original cohort and these 124 non-ARDS patients, we created a binary variable of whether the patient's care team accurately diagnosed ARDS (i.e. ARDS was both diagnosed and present). An accurate diagnosis of ARDS was still a significant predictor of TV after adjusting both for year and for whether ARDS was present (−0.65 mL/kg, adjusted p = 0.002, Supplementary table 2). In contrast, ARDS itself was not a significant predictor in this multivariable analysis (p = 0.22), suggesting that specifically diagnosing ARDS was important for initiating LTVV.

To find covariates independently associated with recognition, we performed a multivariable analysis using factors associated with ARDS recognition from univariate analysis. AKI, year, and sepsis remained independently associated with recognition (Supplementary table 3). In a separate analysis, we also included variables previously found to be associated with recognition (1) (Supplementary table 4), including age, pneumonia, history of CHF, Pa_{O_2}/F_{IO_2}, and volume overload. AKI, sepsis, and year remained independent predictors of recognition.

Patients for whom ARDS was recognized had greater 60-day in-hospital mortality (57% vs. 33%, p = 0.012) and fewer ventilator-free days (median 0, interquartile range 0–23 vs. median 21, interquartile range 0–25, p = 0.026). However, in multivariable regression, the association between ARDS recognition and mortality was confounded by variables that largely reflect illness severity (Supplementary table 5). Tidal volume itself was not significantly associated with mortality in univariate analysis (p = 0.43).

Discussion

This study reports that ARDS at our academic medical center has been under-recognized, but recognition has improved recently. ARDS recognition was more common for patients with more severe illness and was associated with use of LTVV. Recognizing ARDS is often the first step in appropriately treating patients with LTVV, which decreases mortality in ARDS.

Multiple factors could explain the recent increased recognition at our institution. In January 2016, the ICU admission workflow changed so that LTVV became the default strategy for all intubated patients. Consistently, 2016 exhibited the greatest recognition and LTVV use (Figure 2). However, these outcomes also improved over several years prior to 2016, likely because ICU providers have been provided with data on ordering practices regarding LTVV and have received reminders of the benefits of LTVV through lectures, staff meetings, and huddles.

Although we observed vasopressor use and AKI to be associated with ARDS recognition, other authors have found different associated patient and provider factors. Bellani et al. found higher nurse- and physician-to-patient ratios, younger patient age, lower Pa_{O_2}/F_{IO_2}, and the presence of pneumonia or pancreatitis to be associated with recognition (1). No patient in our study had ARDS associated with pancreatitis, and physician- and nurse-to-patient ratios were unavailable, although these ratios would likely have low variability at the study site, where nurse-to-patient ratios are mandated to be either 1:1 or 1:2. We also noted that ARDS recognition was associated with fewer ventilator-free days and increased mortality, despite it being associated with LTVV use, which improves mortality (2). However, based on multivariable analyses, we found that recognition's association with increased mortality was confounded with variables related to illness severity. Additionally, this univariate association with mortality is likely not novel. Recognition has previously been shown to be associated with lower Pa_{O_2}/F_{IO_2} ratio (1) and increased ARDS severity (10), which are associated with increased mortality (1).

Documentation of ARDS is a surrogate for provider recognition; providers could potentially recognize ARDS without documenting it in the medical record. However, given how infrequently ARDS was reported to be recognized in prior literature and how marked the change has been at UCSF, in our view this trend is unlikely due solely to changes in documentation practices. The substantially lower use of LTVV in patients for whom ARDS was unrecognized also suggests that our measurement of documentation reflects true recognition. We further increased sensitivity for variable documentation practices by adopting a broad definition of ARDS recognition and by reviewing all provider notes while

the patient was in the ICU, rather than only those immediately surrounding the onset of ARDS. It is possible that ARDS could be documented in ways that our search terms (Supplementary table 1) would not identify. However, over 90% of ARDS cases were recognized in 2016, and the search terms should have been similarly sensitive over the course of this study because consensus terminologies and definitions have been in use for decades (14). Thus, even if all cases were truly recognized in 2016, our search would be approximately 90% sensitive for recognition. We also included “ALI” and “lung injury,” which were potentially more commonly used prior to the Berlin criteria from 2012 (11).

Providers may disagree about whether a patient has ARDS because of chest radiograph interpretation (15, 16), identification of an ARDS risk factor, or the judgment that volume overload rather than lung injury contributed to pulmonary edema (17). Therefore, providers may not have recognized ARDS because they reviewed the appropriate data but thought that it was simply not present. In order to increase our sensitivity for these cases, we included patients for whom 1) ARDS was only in the differential diagnosis or 2) pulmonary edema was potentially related to both lung injury and cardiac etiologies. Notably, having mixed cardiogenic and non-cardiogenic etiologies of lung injury, as determined by our expert consensus review of each case, was not associated with ARDS recognition.

Our study has multiple strengths. No prior studies to our knowledge have explored the several ways that providers could recognize ARDS, such as including it in the differential diagnosis or by mentioning LTVV but not ARDS itself. Having a broader definition of ARDS recognition could help explain why we observed an association between ARDS recognition and lower TVs while other studies found either increased TVs with a documented ARDS diagnosis (4) or minimal differences in TVs (1, 6). Additionally, in most studies, with two exceptions (4, 7), the adjudication of ARDS diagnosis was not performed by multiple experts reviewing each case. We also retrospectively searched all ICU documentation by all primary and critical care providers for ARDS recognition. In contrast, other studies have prompted providers with a survey that included the possibility of ARDS (1); focused on the 48 hours after ARDS criteria were met (5); or reviewed only coding, death certificates, and discharge summaries (18). Lastly, our study is also unique in its more rigorous description of the search terms and how the search for recognition was performed using unstructured clinical text. Future studies could improve on our automated search methods by using approximate string matching to account for variable ways of referring to ARDS and by automatically excluding phrases that are often found when searching for “ARDS” but which would never reflect recognition (e.g. when a provider has “consulted cards”). Modern natural language processing algorithms could also be leveraged to more efficiently identify recognition.

Our study also has limitations. It is possible that the apparent increase in ARDS recognition could be related to the different chart review methods we employed for each medical record system. However, there were no major differences between the chart review methods in a limited automated re-review of the manually reviewed charts (Supplementary Methods). While our search methods could have missed recognition due to typographical errors, these are unlikely to substantially decrease the search sensitivity because when ARDS was recognized, it was usually recognized by multiple providers. Lastly, the data from our study

comes from a single hospital, and other institutions could have different rates of ARDS recognition, documentation practices, or variables associated with recognition. For example, different ICU provider structures may affect recognition, as it might LTVV use (19). However, while estimates of recognition have varied widely in the literature (1, 4, 5, 7–9), the trend of increased recognition likely is not unique to UCSF because of the increased appreciation in the literature of under-recognition and insufficient LTVV. Additionally, while focusing on a single institution may make some findings less generalizable, the resulting institutional consistency may have resulted in less variability in clinical practice, thus making differences in, for example, ventilator settings easier to discover. Between the recognized and unrecognized ARDS cases, we found a larger difference in mean TV than Bellani et al. did (0.9 vs. 0.2 mL/kg). Another advantage to our single-hospital approach is that we would expect high rates of ARDS recognition and LTVV use because the hospital is part of the NHLBI ARDS Clinical Trials Network and now the PETAL Network and because all ICU patients have multiple teams who should consider ADRS. Nevertheless, ARDS was still under-recognized and LTVV inconsistently used.

Conclusions

ARDS recognition and LTVV use have increased substantially over the past several years but remain less than optimal. Because of the mortality benefit of LTVV, awareness of ARDS and LTVV will continue to be important. Future studies could focus on whether specific interventions, such as EMR alerts or making LTVV easier to order, increase ARDS recognition or use of LTVV.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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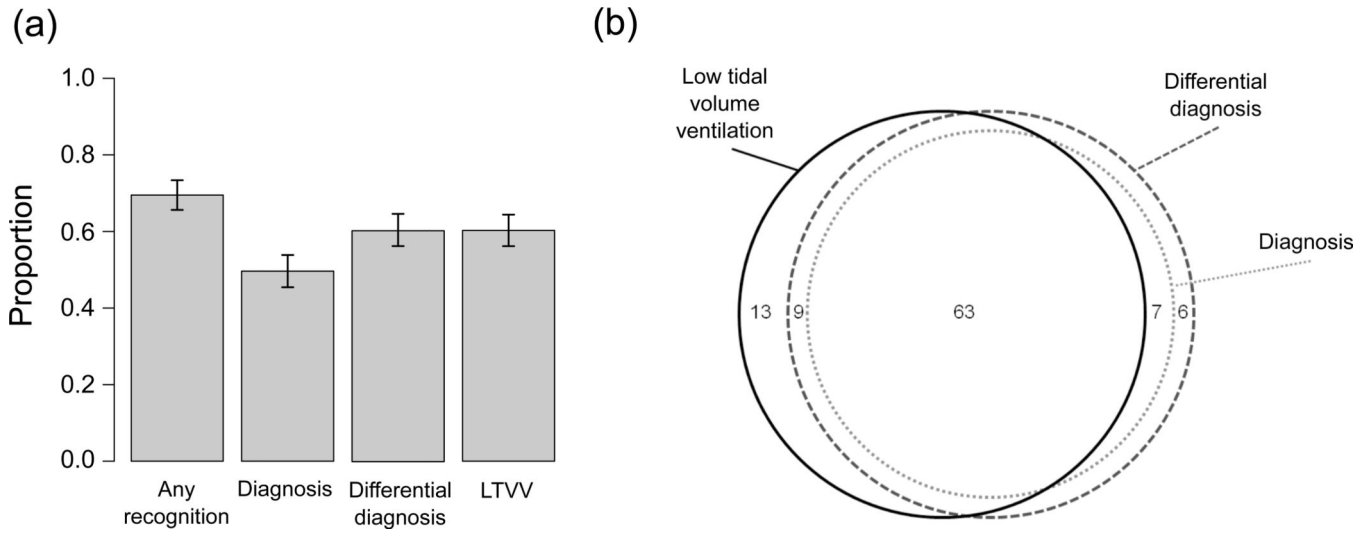

Figure 1: Frequencies of different types of ARDS recognition.

(a) ARDS recognition by type of recognition: any recognition, diagnosis of ARDS, differential diagnosis including ARDS, or mention of low tidal volume ventilation (LTVV). (b) Overlap between different types of recognition for each patient, with diagnosed cases also considered to be in the differential diagnosis.

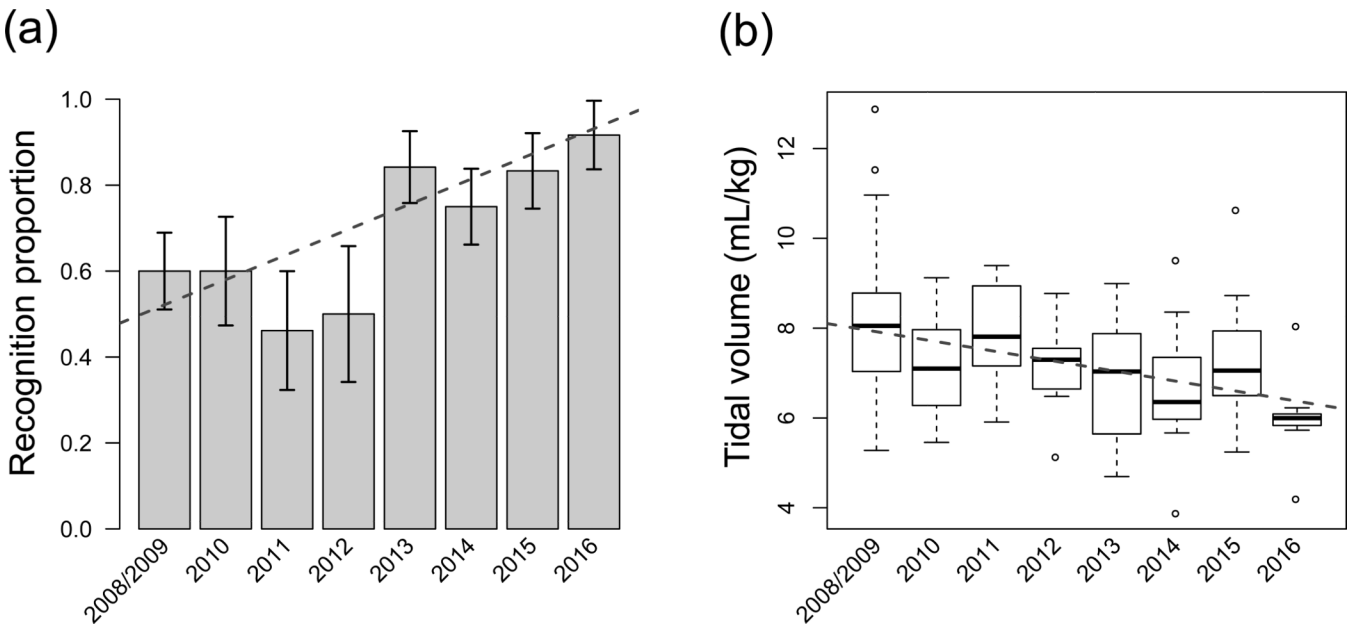

Figure 2: ARDS recognition rates by year.

(a) Rates of ARDS recognition at the UCSF Moffitt-Long hospital between 2008 and 2016 increased significantly for each year ($p = 0.004$). Only two patients met criteria for ARDS in 2008 in our study, so they were grouped with patients in 2009. Error bars are standard errors of the proportions. (b) Boxplots of tidal volumes across each year, which decreased significantly over time ($p < 0.0001$). Both (a) and (b) have overlying, dark gray, dotted linear regression lines to show the trends of recognition proportion and tidal volume, respectively.

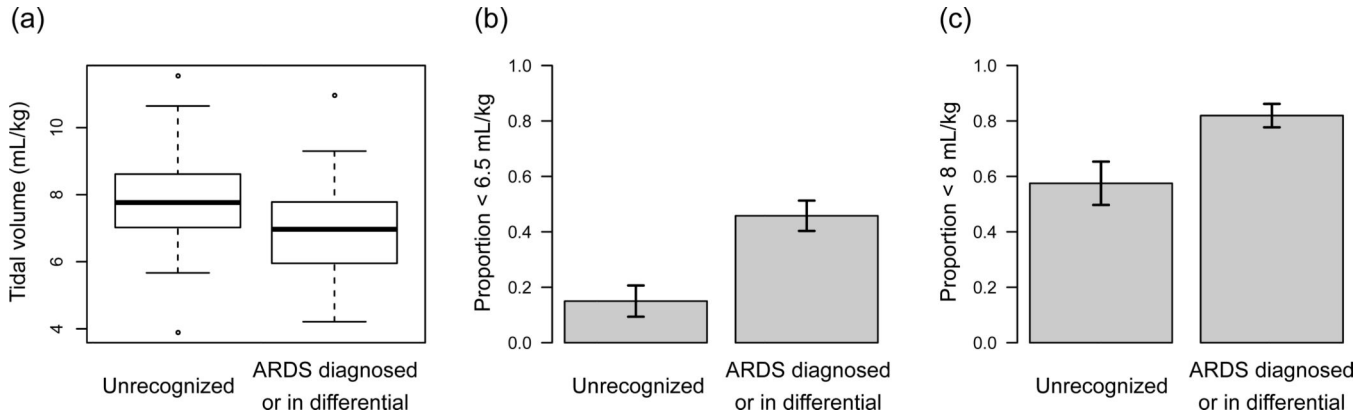

Figure 3: ARDS recognition vs. tidal volume.

(a) Patients for whom ARDS was diagnosed or in the differential diagnosis had significantly lower tidal volumes ($p = 0.001$), specifically with increased use of tidal volumes (b) less than 6.5mL/kg ($p = 0.0008$) and (c) less than 8mL/kg ($p = 0.008$). In these analyses, we excluded cases where ARDS was recognized but where the only form of recognition was mention of ARDS treatment, rather than also diagnosing ARDS or including it in the differential diagnosis.

Table 1:
Study participant characteristics and provider specialty vs. ARDS recognition.

Listed data are means with standard deviations, frequencies associated with percents of unrecognized or recognized cases, or in cases where a rank-sum test was used, medians with interquartile ranges. Bold variables are significantly different in univariate analysis between the two groups ($p < 0.05$).

Clinical covariates		ARDS unrecognized (n = 43)	ARDS recognized (n = 98)	P-value
	Age	66 (17)	67 (16)	0.69
	BMI	27.9 (10.1)	25.3 (7.8)	0.15
	Male gender	25 (58%)	54 (55%)	0.88
Race	Caucasian	22 (51%)	53 (54%)	0.07
	Asian	10 (23%)	30 (31%)	
	African-American	11 (26%)	10 (10%)	
	Other	0 (0%)	5 (5%)	
Ethnicity	Hispanic	2 (5%)	6 (6%)	>0.99
Risk factor for ARDS	Aspiration	12 (28%)	28 (29%)	>0.99
	Other	0 (0%)	5(5%)	0.32
	Pneumonia	24 (56%)	59 (60%)	0.76
	Sepsis	**32 (74%)**	**89 (91%)**	**0.02**
	Transfusion	7 (16%)	21 (21%)	0.63
Medical comorbidities	COPD/Asthma	11 (26%)	25 (26%)	>0.99
	Other Pulmonary	8 (19%)	8 (8%)	0.13
	Obstructive sleep apnea	5 (12%)	3 (3%)	0.06
	Current or former smoker	20 (47%)	44 (45%)	>0.99
	Congestive heart failure	13 (30%)	24 (24%)	0.61
	Coronary artery disease	11 (26%)	15 (15%)	0.23
	Cardiac arrest	10 (23%)	11 (11%)	0.11
	Other Cardiac	17 (40%)	30 (31%)	0.40
	AKI	**15 (35%)**	**67 (68%)**	**0.0004**
	CKD	14 (33%)	17 (17%)	0.07
Other clinical variables	Full code	33 (79%)	85 (87%)	0.34
	Net fluid balance on first day of admission in L[a]	**+2.8 (IQR +0.4–3.9)**	**+4.2 (+1.4–7.3)**	**0.016**
	Quadrants involved on chest x-ray	3.1 (0.8)	3.3 (0.8)	0.24
	Lung injury only (vs. mixed lung injury and volume overload)	29 (67%)	71 (72%)	0.69
Primary admitting service	Internal Medicine	33 (77%)	77 (79%)	**0.008**
	Cardiology	6 (14%)	4 (4%)	
	Cardiothoracic surgery	2 (5%)	0 (0%)	
	Neurovascular	0 (0%)	2 (2%)	
	General Surgery	1 (2%)	3 (3%)	
	Kidney transplant	1 (2%)	1 (1%)	
	ICU/oncology	0 (0%)	11 (11%)	

[a]Calculated using a rank-sum test and reporting median with interquartile range. For net fluid balance, we also removed the single most extreme positive and negative outliers.

Table 2:
Severity of illness and ventilator settings of study participants vs. ARDS recognition.

Listed data are means with standard deviations, frequencies associated with percents of unrecognized or recognized cases, or in cases where a rank-sum test was used, medians with interquartile ranges. Bold variables are significantly different in univariate analysis between the two groups ($p < 0.05$).

Clinical covariates		ARDS unrecognized (n = 43)	ARDS recognized (n = 98)	P-value
Severity of Illness	**On vasopressors**	**18 (46%)**	**63 (67%)**	**0.04**
	APACHE III	115 (39)	121 (37)	0.38
ARDS severity	**Mild ARDS**	**6 (14%)**	**21 (21%)**	**0.012**[b]
	Moderate ARDS	**25 (58%)**	**31 (32%)**	**0.36**[c]
	Severe ARDS	**12 (28%)**	**46 (47%)**	
	Lung Injury Score	**3.18 (0.27)**	**3.31 (0.34)**	**0.015**
Ventilator settings	**Tidal volume overall (mL/kg)**	**7.8 (1.4)**	**6.9 (1.4)**	**0.001**[d]
	Tidal volume < 6.5 mL/kg	**6 (15%)**	**48 (51%)**	**0.0008**[d]
	Tidal volume < 8 mL/kg	**23 (58%)**	**78 (82%)**	**0.008**[d]
	Respiratory rate[a]	**19.5 (IQR 14.25–24)**	**25 (IQR 18–30)**	**0.0037**
	Positive end-expiratory pressure[a]	**5 (IQR 5–6.5)**	**5 (IQR 5–10)**	**0.035**
	Plateau pressure	23.5 (5.5)	22.4 (6.1)	0.40
	Peak inspiratory pressure	28.4 (7.2)	29.1 (8.0)	0.47
	FIO_2	0.72 (0.24)	0.74 (0.24)	0.60
	PaO_2/FIO_2 ratio (mmHg)	143 (59)	126 (70)	0.15

[a] Calculated using a rank-sum test and reporting median with interquartile range. For net fluid balance, we also removed the single most extreme positive and negative outliers.

[b] Calculated with a chi-squared test. For ARDS severity, the association with recognition is non-linear, and p-values were generated using both a chi-squared test, which shows differences between the severity categories, and a *t*-test, where we treated severity levels as the numbers 1, 2, and 3.

[c] Calculated with a *t*-test.

[d] Calculated after excluding cases where the only form of recognition was documentation of LTVV, rather than also documenting ARDS being diagnosed or in the differential diagnosis.