Barriers to low tidal volume ventilation in acute respiratory distress syndrome: Survey development, validation, and results

Cheryl R. Dennison, ANP, PhD; Pedro A. Mendez-Tellez, MD; Weiwei Wang, MS Eng; Peter J. Pronovost, MD, PhD; Dale M. Needham, MD, PhD

Objective: **To evaluate perceived attitudes, knowledge, and behaviors regarding the use of low tidal volume ventilation in acute respiratory distress syndrome among physicians, nurses, and respiratory therapists in intensive care units.**

Design: **Cross-sectional, self-administered survey.**

Setting: **Large Acute Respiratory Distress Syndrome Network teaching hospital in Baltimore, MD.**

Participants: **Attending, fellow, and resident physicians; staff nurses; and respiratory therapists in three intensive care units.**

Interventions: **A survey was designed to assess barriers related to clinicians' perceived attitudes, knowledge, and behaviors related to low tidal volume ventilation in acute respiratory distress syndrome and intensive care unit organization-related barriers. Survey development was guided by a published framework of barriers to clinician adherence to practice guidelines; individual items were derived through literature review and refined through pilot testing. Content validity, face validity, and ease of use were verified by local clinicians. Psychometric properties were assessed and regression analyses were conducted to examine differences in perceptions and knowledge level by provider discipline and training level.**

Measurements and Main Results: **There were 291 completed surveys with a response rate of 84%. Validity and acceptable psychometric properties were demonstrated. Barriers related to clinician attitudes, behaviors, and intensive care unit organization were significantly higher among nurses and respiratory therapists vs. physicians. Knowledge-related barriers also were significantly higher among nurses vs. physicians and respiratory therapists. Barriers were lower and knowledge test scores higher among fellows and attending physicians vs. residents. Similarly, barriers were lower and knowledge test scores higher among nurses with >10 yrs of experience vs. <10 yrs of experience.**

Conclusions: **Important organizational and clinician barriers, including knowledge deficits, regarding low tidal volume ventilation were reported, particularly among nurses and resident physicians. Addressing these barriers may be important for increasing implementation of low tidal volume ventilation. (Crit Care Med 2007; 35:2747–2754)**

KEY WORDS: acute respiratory distress syndrome; mechanical ventilation; provider practice; survey; critical care; multidisciplinary; evidence-based care

Acute lung injury/acute respiratory distress syndrome (ALI/ARDS) is a common cause of morbidity and mortality in the United States, with important public health implications (1). Improvements in critical care practice, including changes in mechanical ventilation strategies, have decreased short-term mortality rates for ALI/ARDS patients (2). The ARDS Network has demonstrated that a low tidal volume ventilation protocol significantly reduced short-term mortality for ALI/ARDS patients (3). Kallet et al. (4) demonstrated that this protocol could be successfully implemented in clinical practice with improved hospital mortality compared with historical controls. Although some have argued that adoption of the exact ARDS Network protocol may be unnecessary, the existing evidence supports that clinicians should change their practice and adopt lung-protective ventilation for patients with ALI/ARDS (5). However, widespread adoption of this ventilation strategy has not rapidly occurred (5, 6–10). In addition, practice variability by type of clinician and specialty training has been demonstrated. Belda et al. (11) reported that critical care physician specialists, compared with resident physicians, critical care nurses, and respiratory therapists, were more likely to choose the low tidal volume ventilation strategy.

Understanding the existing barriers to use of low tidal volume ventilation is essential to increasing implementation of the current research findings and improving outcomes among ALI/ARDS patients. We developed the *Survey of Ventilator Management in Acute Respiratory Distress Syndrome* to examine clinician knowledge and perceived barriers to use of low tidal volume ventilation. The objectives of this article are to describe the development, preliminary validity, and psychometric properties of the survey and to present results of the survey when

From the School of Nursing (CRD), Division of Pulmonary/Critical Care Medicine (DMN), Department of Anesthesiology/Critical Care Medicine (PAMT, PJP), and Department of Biostatistics, Bloomberg School of Public Health (WW), Johns Hopkins University, Baltimore, MD.

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For information regarding this article, E-mail: cdennis4@jhmi.edu

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administered to a multidisciplinary group of clinicians working in medical and surgical intensive care units (ICUs) at an ARDS Network teaching hospital.

Five *a priori* hypotheses were tested in this report. First, a high degree of organizational and perceived barriers will be reported by survey respondents. Second, the clinicians' perceived barriers and knowledge of low tidal volume ventilation will differ by provider discipline. Third, the perceived barriers and knowledge will differ among physicians by specialty area and training level (i.e., housestaff, fellow, attending). Fourth, the perceived barriers will be lower and knowledge higher among clinicians with a greater number of years of experience and with an increased proportion of time worked in the ICU. Fifth, the perceived barriers will be inversely correlated with clinician knowledge of low tidal volume ventilation.

MATERIALS AND METHODS

Survey Development. The conceptual framework developed by Cabana et al. (12) for understanding barriers to clinician adherence to practice guidelines guided survey development. Clinician adherence is critical in translating recommendations into actions and improved patient outcomes. However, a variety of barriers undermine this process. This framework asserts that lack of awareness and familiarity of a practice guideline hinders clinician knowledge. In addition, clinician attitudes, including lack of agreement with the guideline, motivation, or the inertia of previous practice patterns, are another potential barrier. Despite adequate knowledge and accepting attitudes, external organizational barriers and patient and environmental factors also can affect a clinician's behavior or ability to implement new recommendations.

Based on this framework, our survey was designed to assess clinicians' perceived knowledge, attitudes, and behaviors and to identify ICU organizational barriers to use of low tidal volume ventilation in ARDS. The survey measured clinicians' perceptions of barriers to low tidal volume ventilation using three subscales focused on: Attitudes (ten items), Behaviors (three items), and Knowledge (five items). The Attitudes subscale included items assessing lack of agreement, lack of self-efficacy, lack of outcome expectancy, or the inertia of previous practice (12). The Behaviors subscale included items assessing external barriers that may limit provider ability to perform the recommended behavior.

In addition, the survey measured organizational barriers with three items that were combined to create the ICU Organizational Barriers Scale. A four-item multiple-choice format Knowledge Test was also included. These questions were based on knowledge of the ARDS Network low tidal volume ventilation protocol (available at http://www.ardsnet.org) (13). The survey collected data on provider characteristics, including discipline (i.e., physician, nurse, respiratory therapist), specialty area (i.e., anesthesia, internal medicine, surgery, or other), number of years of ICU experience, and proportion of working time allocated to clinical care in the ICU. The survey also collected data on ICU rounding practices (i.e., nurse and respiratory therapist involvement in rounds) and use of a low tidal volume ventilation protocol for ARDS patients.

Individual survey items assessed provider barriers to low tidal volume ventilation based on general barriers explicated by Cabana et al. (12) and specific barriers to low tidal volume ventilation in ALI/ARDS that were identified in previous research (6, 7, 9, 14, 15). The study investigators reviewed and refined the drafted items. The survey was then pilot tested through administration to six local clinicians, including three physicians representing both the medical ICU and surgical ICUs, one respiratory therapist, and two ICU nurses, who completed the survey and then provided feedback on item wording to ensure ease of use, face validity (i.e., the extent to which the survey seemed to measure the identified construct), and content validity (i.e., the consistency between survey items and the content they were intended to assess) (16). The survey was further refined based on feedback from the local clinicians. For all survey items (excluding the Knowledge Test), a 6-point Likert scale was used, with the following response options: 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree, 6 = do not know. The items alternated between positive and negative wording to avoid response set bias (16). Individual items scores were summed to create subscale scores, and the three subscales were summed to create the Overall Provider Barriers scale score. The 32-item survey required approximately 10 mins to complete.

Study Setting and Sample. The study was set in three intensive care units (one medical and two surgical) at Johns Hopkins Hospital in Baltimore, MD. In these ICUs, ALI patients receive low tidal volume ventilation in approximately 50% of ventilatory assessments (unpublished data), which reflects slow adoption of this strategy, as also reported in other hospitals (5–10). A protocol for low tidal volume ventilation exists in only the medical ICU. Use of this protocol requires a physician order, and in all ICUs, all ventilator changes, including those associated with the protocol, are implemented by respiratory therapists. Physician staffing for each ICU included at least one attending, one fellow, and four residents. In addition, medical ICU staffing included four interns. Nurse (one nurse per two patients) and respiratory therapist (one respiratory therapist per eight to ten patients) staffing patterns were consistent across the ICUs.

Education regarding ALI/ARDS and lung-protective ventilation is not standardized across units or disciplines. Nurses, during critical care orientation, receive didactic lecture on mechanical ventilation modes and ALI/ARDS. Additional patient-based teaching provided by the preceptor during nurse orientation is not standardized. Respiratory therapists, during orientation, rotate through the medical ICU and are introduced to the ARDS protocol at that time; however, they do not receive any formal or standardized ALI/ARDS educational content. As part of their clinical training, interns, residents, and fellows are exposed to teaching on ALI/ARDS and mechanical ventilation; however, this teaching is not standardized and varies both within and between ICUs based on which attending physician provides the teaching as part of his or her medical education responsibilities.

In May and June 2005, we conducted a cross-sectional, self-administered survey in this study setting. The survey was provided to attending, fellow, and resident physicians; staff nurses; and respiratory therapists. Full or part-time clinicians were eligible for inclusion. Participants were recruited by one of the study investigators (CRD, DMN, PAMT), who provided a study overview and obtained oral consent.

Procedures. Physicians were recruited at weekly case conferences and rounds, and nurses and respiratory therapists were recruited at staff meetings with mandatory attendance. Surveys were anonymously completed and immediately returned by these participants. In addition, to encourage participation among fellows and attending physicians who may have been more difficult to reach, the survey was made available through internal mail and as an e-mail attachment. This route of survey administration was utilized three times within a 6-wk period to maximize participation. These anonymous surveys were returned to a conveniently located hospital mailbox. As this was an anonymous survey, there was no feasible mechanism to ensure that no one submitted more than one survey; however, it is unlikely that the busy clinicians would spend their limited time repeating the survey.

Psychometric Testing and Scoring of Survey. For each item, the mean, SD, and distribution of scores were examined. For each scale, the item-scale correlation, Cronbach's alpha and inter-scale correlations were examined (16, 17). To explore the criterion validity of the perceived Knowledge subscale, we examined its relationship with the Knowledge Test and with a survey item that globally assessed the provider's perceived knowledge level.

Negatively worded items were recoded for consistency with positively worded items, maintaining the anchor of 3 and 6 for "neutral" and "do not know" responses, respectively. Raw scores for the Overall Provider Barriers scale and the three subscales were calculated as the sum of responses from the recoded items. These raw scores were trans-

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Table 1. Respondents' characteristics

	n[a]	%
Discipline		
Nurse	82	28
Respiratory therapist	19	7
Physician	190	65
Training level[a]		
Intern	37	20
Resident	102	54
Fellow	29	16
Attending physician	18	10
Primary medical specialty[a]		
Anesthesiology	64	34
Internal medicine	97	50
Surgery	19	10
ICU experience, yrs		
Currently in training[b]	162	56
0–5	54	18
6–10	31	11
11–15	15	5
>15	29	10
Annual working time allocated to ICU, %[c]		
<20	128	44
20–40	45	15
41–60	14	5
61–80	14	5
81–100	89	31

ICU, intensive care unit.

[a]Unless otherwise specified, the number of respondents for each question was 291 clinicians. For the two questions related to the 190 physician respondents (i.e., training level and primary medical specialty), the total number of respondents was 186 and 180, respectively; [b]all respondents who classified themselves as in training were physicians; see physician training levels described further above; [c]data missing for one respondent.

formed into uniform scales ranging from 0 to 100, with higher scores indicating greater perceived barriers to use of low tidal volume ventilation. Knowledge test items were recoded as correct or incorrect, and a sum score was calculated. This Knowledge Test score ranged from 0 to 4, with a higher score indicating a higher knowledge level.

Data Analysis. Due to nonnormality of the Perceived Barriers overall scale, subscales, and Knowledge Test scores, the Mann-Whitney U test was used to examine differences between groups. Separate linear regression models were used to examine dependence of the Overall Provider Barriers scale, three subscales, and ICU Organizational Barriers scale on the following covariates: discipline, years of experience, and proportion of work time allocated to the ICU. A logistic regression model was used to examine the association of these same covariates for the Knowledge Test, which was dichotomized as high (score of ≥3) vs. low (score of <3) knowledge. These models were examined for the total sample and for nurses and respiratory therapists independently. For physicians, the covariates included in the models were: specialty, training level, and proportion of annual time in the ICU. A value of $p < .05$ was considered statistically significant in all analyses. The R software was used for all analyses (18). The study was approved by the Johns Hopkins Medicine Institutional Review Board.

RESULTS

The survey was provided to 348 clinicians, with 291 responses received (84% response rate). By discipline, response rates were: 84% for physicians (190/226), 80% for nurses (82/102), and 95% for respiratory therapists (19/20).

Respondent Characteristics. Respondent characteristics are provided in Table 1. Among physicians, 20% were interns, 54% residents, 16% fellows, and 10% attending physicians. Physicians identified their primary specialty as: anesthesiology, 34%; internal medicine, 50%; surgery, 10%; and neurology, <1% (not reported, 5%). The majority of the sample had <5 yrs of ICU experience, with 56% currently in training. The majority of the sample spent ≤60% of their annual working time in the ICU.

Psychometric Analysis. The proportion of missing values for individual items ranged from 0.7% to 5.2%, with the vast majority of items missing ≤2.5% of responses. The response option frequency distribution and mean and SD by provider group for each survey item are presented in Table 2. For all subscales, the item response option frequency distributions were relatively symmetrical, and within each scale, items had a similar SD, supporting the scaling assumption of equal item variance (16).

The Cronbach's alpha coefficients of internal reliability were acceptable, at ≥0.78 for all scales, except the Behaviors subscale, which was 0.64, likely due to it containing only three items (Appendix 1). Inter-scale correlations were 0.54 to 0.94. The correlation between each item and the postulated subscale and the Overall Provider Barriers scale exceeded 0.50 for most items, demonstrating internal consistency in item scaling (Appendix 2) (16). Item-subscale correlations within each subscale were generally similar, supporting the assumption that most items in a scale contain approximately the same proportion of information about the represented concept.

Criterion validity of the Knowledge subscale and Knowledge Test was supported. The global provider knowledge item was inversely correlated with the Provider Barriers Knowledge subscale ($r = -.50$, $p < .001$) and positively correlated with the Knowledge Test ($r = .36$, $p < .001$), indicating that clinicians' self-perception of inadequate global knowledge was significantly correlated with high perceived knowledge barriers and a low score on the survey's objective measure of knowledge.

Hypothesis Testing. Physicians had significantly lower barriers for all scales/subscales and for the Knowledge Test compared with nurses (Table 3). Respiratory therapists also had lower barriers for the Knowledge subscale and the Knowledge Test than nurses. Physicians reported lower barriers than respiratory therapists for the Overall Provider Barriers scale, Attitudes and Behaviors subscales, and ICU Organizational Barriers scale.

Compared with physicians in surgery and anesthesiology specialties, internal medicine physicians generally reported lower barriers and had higher Knowledge Test scores (Table 4). Interns, compared with all other training levels of physicians, generally demonstrated higher barriers and a lower mean score on the Knowledge Test (Table 4). Residents, compared with fellows, had higher barriers for all subscales and, when compared with attending physicians, had higher barriers for the Overall Provider Barriers scale, Knowledge subscale, ICU Organizational Barriers scale, and Knowledge Test. Residents' mean score on the Knowledge Test was significantly lower than both fellows and attending physicians.

Perceived barriers and Knowledge Test scores were also compared within discipline by years of experience for nurses and respiratory therapists (Table 5). Higher barrier levels were reported by nurses with <10 yrs of ICU experience on the Overall Provider Barriers scale, Attitudes subscale, and ICU Organizational Barriers scale in comparison with those with ≥10 yrs of experience. There were no significant differences by years of experience among respiratory therapists.

Regression Analyses. For the entire sample, the Overall Barriers Scale, Attitudes subscale, Knowledge subscale, ICU Organizational Barriers scale, and Knowledge Test scores were associated with discipline and years of ICU experience. The Behaviors subscale was associated only with discipline. Among physicians, all scale and subscale scores were dependent on training level and specialty (Table 6). Among nurse and respiratory therapists,

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Table 2. Response option frequency distribution and item mean (SD) by provider group

Subscale	Item No.	Item	Response Option Frequency Distribution, %[a]						Item Score Mean (SD)		
			1	*2*	*3*	*4*	*5*	*6*	RN	RT	MD
Attitudes	8[b]	My ARDS patients usually are too sick to use it	<1	3	8	38	42	8	4 (1)	3 (1)	5 (1)
	9[b]	My ARDS patients usually have contraindications to use of it	0	2	9	47	30	11	4 (1)	3 (1)	4 (1)
	12	Physicians in my ICU are knowledgeable of the use of low tidal volume ventilation	31	50	10	5	1	3	3 (1)	3 (1)	2 (1)
	16	My colleagues are aware of low tidal volume ventilation for ARDS patients	24	52	9	4	2	7	3 (2)	2 (1)	2 (1)
	17[b]	I believe that low tidal ventilation will harm my patients	0	1	7	39	48	3	4 (1)	4 (1)	5 (1)
	18[b]	It often requires teaching or argument to convince other ICU team members to use low tidal volume ventilation for ARDS	1	9	17	36	27	8	4 (1)	3 (1)	4 (1)
	19[b]	Care provided by physicians is more labor intensive with low tidal volume ventilation vs. conventional ventilation	2	17	14	37	19	7	4 (1)	3 (1)	4 (1)
	20[b]	Care provided by nurses is more labor intensive with low tidal volume ventilation vs. conventional ventilation	3	21	20	34	10	8	4 (1)	3 (1)	4 (1)
	21[b]	Care provided by respiratory therapists is more labor intensive with low tidal volume ventilation vs. conventional ventilation	6	40	13	19	8	9	3 (2)	2 (1)	3 (1)
	22[b]	Compared with conventional ventilation, low tidal volume ventilation requires more sedation of patients	14	39	10	20	4	10	3 (2)	2 (2)	3 (1)
Behaviors	23	Except when there are specific contraindications, I always use/recommend low tidal volume ventilation for ARDS	24	40	18	10	1	6	3 (1)	3 (1)	2 (1)
	24	Our ICU team always discusses airway pressures during rounds for patients with ARDS	19	50	12	11	3	4	3 (1)	3 (2)	2 (1)
	25	Our ICU team always discusses tidal volume in terms of cubic centimeter (cc) per kilogram of predicted body weight during rounds for patients with ARDS	8	34	18	24	6	9	4 (1)	3 (1)	3 (1)
Knowledge	10	I am familiar with the ventilatory settings necessary to achieve low tidal volume ventilation	27	48	12	4	4	4	3 (1)	2 (1)	2 (1)
	11	I believe that ARDS patients who receive low tidal volume ventilation, compared with traditional ventilation, are more likely to survive	24	52	14	3	1	6	3 (2)	3 (1)	2 (1)
	13[b]	A special device (other than the mechanical ventilator) is required to measure airway pressure	1	5	9	45	24	13	4 (1)	4 (1)	4 (1)
	14[b]	When using low tidal volume ventilation, the plateau pressure is set, just like tidal volume and FIO_2	1	8	2	33	38	17	4 (1)	5 (1)	5 (1)
	15[b]	A special type of mechanical ventilator is required to do low tidal volume ventilation	1	7	2	40	42	6	4 (1)	4 (1)	4 (1)
ICU Organizational Barriers	26	My ICU gives us adequate education on how to ventilate ARDS patients	16	44	16	16	5	3	3 (1)	3 (1)	2 (1)
	27[b]	RN-to-patient staffing ratio in my ICU is not sufficient for managing patients with low tidal volume ventilation	1	4	10	46	29	8	4 (1)	4 (1)	4 (1)
	28[b]	RT-to-patient staffing ratio in my ICU is not sufficient for managing patients with low tidal volume ventilation	1	9	13	42	23	10	4 (1)	4 (1)	4 (1)
Knowledge Test	29	An important goal of lung protective mechanical ventilation for ARDS is to: 1. Maintain PaO_2 >60 mm Hg at the lowest possible PEEP 2. Keep peak airway pressure <35 cm H_2O 3. Keep plateau pressure <30 cm H_2O 4. Keep tidal volume <10 mL/kg of predicted body weight 5. I don't know	9	10	53[c]	16	10	—	—	—	—
	30	An ARDS patient is receiving lung protective mechanical ventilation with a tidal volume of 6 mL/kg predicted body weight, respiratory rate of 35 breaths/min, plateau pressure of 26 cm H_2O. What would be your next intervention if the reported ABG demonstrates a pH of 7.25 and a PCO_2 of 55 mm Hg? 1. Increase the respiratory rate to 38 breaths/min 2. Increase the tidal volume to 7 mL/kg 3. Initiate bicarbonate infusion[c] 4. Repeat ABG in 4 hrs[c] 5. I don't know	24	18	2[c]	43[c]	9	—	—	—	—

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Table 2. —*Continued*

Subscale	Item No.	Item	Response Option Frequency Distribution, %[a]						Item Score Mean (SD)		
			1	*2*	*3*	*4*	*5*	*6*	RN	RT	MD
Knowledge Test, continued	31	In an ARDS patient receiving a tidal volume of 5 mL/kg predicted body weight, in which circumstance below would you increase the tidal volume by 1 mL/kg: 1. Peak pressure is <30 cm H_2O 2. Arterial pH 7.25 and respiratory rate of 25 breaths/min 3. Plateau pressure is ≤25 cm H_2O[c] 4. PaO_2 is 55 mm Hg on FIO_2 of 0.5 and PEEP of 10 cm H_2O 5. I don't know	3	21	38[c]	10	25	—	—	—	—
	32	An ARDS patient is receiving a tidal volume of 6 mL/kg predicted body weight, respiratory rate of 30 breaths/min, FIO_2 of 0.8, and PEEP of 14 cm H_2O. The peak pressure is 38 cm H_2O, and plateau pressure is 28 cm H_2O. What would be your next intervention if the reported ABG on this ventilatory setting is: pH 7.31, PCO_2 = 58 mm Hg, and PaO_2 = 59 mm Hg? 1. Increase FIO_2 to 0.9 2. Increase plateau pressure by 2 cm H_2O 3. Decrease tidal volume by 1 mL/kg IBW 4. No changes on current ventilatory settings[c] 5. I don't know	20	6	8	44[c]	18	—	—	—	—

RN, registered nurse; RT, respiratory therapist; MD, physician; ARDS, acute respiratory distress syndrome; ICU, intensive care unit; PEEP, positive end-expiratory pressure; ABG, arterial blood gases; IBW, ideal body weight.

[a]Response options were as follows: 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree, 6 = I don't know; [b] response options were reverse coded for subsequent analyses; [c] indicates correct response(s) to Knowledge Test items.

Table 3. Provider barriers and knowledge by discipline

Scale or Subscale	RN (n = 82)	RT (n = 19)	Physician (n = 190)
Overall Provider Barriers Scale[a]	39 (20)	35 (7)	25 (14)[b,c]
Attitudes Subscale[a]	39 (22)	40 (6)	27 (15)[b,c]
Behaviors Subscale[a]	42 (20)	39 (22)	29 (19)[b,c]
Knowledge Subscale[a]	37 (23)	21 (10)[b]	21 (19)[b]
ICU Organizational Barriers Scale[a]	36 (22)	30 (13)	26 (23)[b,c]
Knowledge Test[d]	1.1 (1.2)	2.6 (1.0)[b]	2.2 (1.3)[b]

RN, registered nurse; RT, respiratory therapist; ICU, intensive care unit.

[a]Scale and subscales have been transformed to a 0–100 scoring system, with a higher score indicating a greater level of barriers; [b]$p < .05$ by Mann-Whitney U test, group comparison to RN; [c]$p < .05$ by Mann-Whitney U test, group comparison to RT; [d]range of possible scores of 0–4, with a higher score reflecting a higher level of knowledge. Data presented as mean (SD).

none of the covariates included in the models were statistically significant.

DISCUSSION

Our study demonstrated that perceived barriers and knowledge deficits regarding the use of low tidal volume ventilation for ARDS are common and vary by caregiver type and experience. This single-center, multidisciplinary survey had a high overall response rate, exceeding 80%, and acceptable preliminary psychometric estimates were demonstrated for its theoretically derived scales.

Important barriers to the use of low tidal volume ventilation were identified across ICU clinicians, with significant differences in the level of perceived barriers and knowledge by clinician group and among physicians by training level and specialty area. Overall, organizational barriers and perceived barriers related to clinician attitudes and behaviors were lower among physicians compared with nurses and respiratory therapists. Both providers' perceptions of their knowledge and a brief objective Knowledge Test revealed significantly more barriers among ICU nurses compared with physicians and respiratory therapists.

Physicians specializing in internal medicine (including pulmonary/critical care) perceived lower barriers and scored higher on the Knowledge Test compared with surgery and anesthesiology specialists. At our hospital, this finding may be because >85% of all ARDS patients are cared for in the medical ICU (which has a low tidal volume ventilation protocol) by internal medicine–trained intensivists. Alternatively, it may be due to a nonrepresentative sample due to the relatively small sample size, particularly within the surgery specialty (n = 19).

Barriers were lower and Knowledge Test scores higher among fellows and attending physicians vs. interns and residents, who have much less experience working in the ICU. Among nurse respondents, those with <10 yrs of ICU experience reported higher overall and attitude-related barriers and organizational barriers. Although this result may not be generalizable, it may highlight a potential benefit of preceptor or mentoring relationships between newer and more experienced nurses. It is essential to provide nurses with the necessary knowledge and organizational support to fully participate as ICU team members, especially because they are often respon-

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Table 4. Provider barriers and knowledge among physicians by specialty area and training level

	Specialty[a]			Training Level[b]			
	Surgery (n = 19)	Anesthesiology (n = 64)	Internal Medicine (n = 96)	Intern (n = 37)	Resident (n = 102)	Fellow (n = 29)	Attending (n = 18)
Overall provider scale	37 (23)	30 (13)	21 (11)[c,d]	34 (19)	25 (12)[e]	16 (7)[e,f]	19 (7)[e,f]
Attitudes subscale	35 (26)	28 (14)	24 (13)	36 (22)	26 (12)[e]	18 (10)[e,f]	25 (8)
Behaviors subscale	44 (19)	33 (17)[d]	24 (17)[c,d]	39 (22)	28 (16)[e]	21 (12)[e,f]	21 (18)[e]
Knowledge subscale	29 (24)	30 (20)	14 (15)[c,d]	30 (22)	23 (19)	11 (10)[e,f]	8 (11)[e,f]
ICU organizational barriers scale	37 (31)	32 (20)	19 (21)[c,d]	38 (29)	26 (21)	13 (10)[e,f]	14 (15)[e,f]
Knowledge test	1.4 (1.3)	1.9 (1.2)	2.5 (1.2)[c,d]	1.1 (1.1)	2.1 (1.2)[e]	3.1 (0.8)[e,f]	3.4 (0.7)[e,f]

ICU, intensive care unit.

[a]Excluded from analyses were those with a medical specialty area of neurology (n = 1) or not reported (n = 10); [b]data on training level was missing for n = 4; [c]$p < .05$, group comparison to anesthesiology; [d]$p < .05$, group comparison with surgery; [e]$p < .05$, group comparison to interns; [f]$p < .05$, group comparison to residents. Data presented as mean (SD). Scale and subscales have been transformed to a 0–100 scoring system, with a higher score indicating a greater level of barriers. The score for the knowledge test ranges from 0 to 4, with a higher score indicating greater knowledge.

Table 5. Provider barriers and knowledge among nurses and respiratory therapists by years of experience

	Overall Provider Barriers Scale	Attitudes Subscale	Behaviors Subscale	Knowledge Subscale	ICU Organizational Barriers Scale	Knowledge Test
Nurse						
0–10 yrs (n = 54)	43 (21)[a]	43 (23)[a]	44 (21)	40 (25)	41 (21)[a]	1.0 (1.0)
>10 yrs (n = 28)	32 (15)	30 (19)	39 (18)	32 (20)	27 (21)	1.3 (1.5)
Respiratory therapist						
0–10 yrs (n = 11)	35 (7)	41 (6)	37 (22)	20 (11)	27 (12)	2.8 (0.8)
>10 yrs (n = 8)	35 (7)	38 (5)	42 (22)	24 (9)	33 (14)	2.3 (1.3)

ICU, intensive care unit.

[a]$p < .05$, >10 yrs vs. <10 yrs experience. Data presented as mean (SD). Scale and subscales have been transformed to a 0–100 scoring system, with a higher score indicating a greater level of barriers. The score for the knowledge test ranges from 0 to 4, with a higher score indicating greater knowledge.

Table 6. Results of regression analyses of provider and ICU organizational barriers and knowledge test scores for physicians (n = 190)

	Overall Provider Barriers Scale β (95% CI)[a]	Attitudes Subscale β (95% CI)[a]	Behaviors Subscale β (95% CI)[a]	Knowledge Subscale β (95% CI)[a]	ICU Organizational Barriers Scale β (95% CI)[a]	Knowledge Test, High vs. Low Score Odds ratio (95% CI)[b]
Training level						
Attending	−17 (−25 to −9)	−12 (−21 to −3)	−19 (−30 to −8)	−28 (−39 to −17)	−29 (−42 to −15)	91 (12 to 1071)
Fellow	−15 (−22 to −7)	−13 (−21 to −4)	−21 (−31 to −11)	−18 (−28 to −8)	−24 (−36 to −12)	28 (6 to 190)
Residents	−11 (−17 to −6)	−11 (−17 to −5)	−15 (−22 to −7)	−14 (−21 to −7)	−18 (−26 to −9)	8 (2 to 30)
Intern	Reference	Reference	Reference	Reference	Reference	Reference
Specialty						
Anesthesiology	11 (7 to 15)	7 (2 to 12)	11 (5 to 17)	19 (13 to 25)	17 (10 to 24)	0.2 (0.07 to 0.4)
Surgery	16 (8 to 24)	12 (3 to 20)	15 (4 to 25)	14 (4 to 23)	16 (5 to 28)	0.1 (0.01 to 0.5)
Internal medicine	Reference	Reference	Reference	Reference	Reference	Reference
Annual time in ICU						
20–40%	0 (−5 to 4)	0 (−6 to 5)	−2 (−9 to 4)	0 (−6 to 6)	−1 (−9 to 7)	1 (0.5 to 4)
41–60%	−5 (−15 to 6)	−6 (−18 to 6)	2 (−12 to 16)	−6 (−20 to 8)	−4 (−21 to 13)	1 (0.1 to 31)
61–80%	−13 (−25 to −2)	−13 (−27 to 0)	−2 (−17 to 14)	−10 (−25 to 4)	−3 (−21 to 16)	5 (0.5 to 76)
81–100%	−7 (−18 to 4)	−13 (−25 to −1)	9 (−5 to 24)	−4 (−19 to 10)	−14 (−31 to 3)	2 (0.2 to 22)
<20%	Reference	Reference	Reference	Reference	Reference	Reference

ICU, intensive care unit.

[a]Multivariable linear regression models were used to examine the association of the Overall Provider Barriers Scale and subscales with the covariates described in the table. The results are presented as the difference in mean scale/subscale score (range of 0–100, with a higher score representing a higher barrier) between the covariate and its reference category; [b]a multivariable logistic regression model was used to examine the association of the Knowledge Test score (range of 0–4, dichotomized as high [≥3] vs. low [<3] score) on the covariates described in the table. The results are presented as the odds ratio for a high vs. low test score for each covariate vs. its reference category.

sible for direct implementation of evidence-based practices.

Responses to several individual survey items provide information that may guide efforts to improve compliance with low tidal volume ventilation. In particular, the responses for items 19, 20, and 21 (Table 2) indicated that 19–46% of respondents perceived that low tidal volume ventilation is more labor intensive for physicians, nurses, and respiratory therapists. This perception may mean

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that clinicians need to be strongly convinced of the benefits of low tidal volume ventilation to outweigh the perceived burden of implementation. The implementation of system-level interventions such as a ventilation protocol may also be advantageous. The responses to item 22 reflect the relatively widespread belief that increased sedation is required to achieve low tidal volume ventilation. However, this belief has been refuted by recent studies reporting that there was no increased use of sedation or neuromuscular blockade among ALI patients treated with low tidal volume ventilation compared with conventional ventilation (14, 15). Educating staff may be important to reduce this barrier.

Finally, items 24 and 25 are noteworthy in that only 42% of respondents at least "agreed" that their ICU team discusses tidal volume in terms of milliliters per kilogram of predicted body weight, whereas 69% discuss airway pressures. A recent secondary analysis of the ARDS Network low tidal volume ventilation trial reinforced that both plateau pressure and tidal volume (measured relative to predicted body weight) are important components of this ventilation strategy (19). Based on our clinical experience in the ICUs participating in this survey, we suggest that the infrequent discussion of tidal volume in terms of milliliters per kilogram of predicted body weight may be because predicted body weight is not readily available. Routinely reporting predicted body weight and tidal volume in milliliters per kilogram of predicted body weight in the ICU medical record and standardizing communication of these issues using a tool, such as a "Daily Goals" sheet (20), may address this issue. Furthermore, explicitly incorporating these issues into a low tidal volume ventilation protocol may also be beneficial.

These results identify a need to develop and test educational interventions, which may involve didactic content, case study analysis, and simulation, and to introduce system-level interventions, such as low tidal volume ventilation protocols and audit and feedback systems, to improve clinicians' understanding and use of this evidence-based intervention (21). Methods described in the literature have included a Web-based teaching tool to reduce practice variability (11), training videos for respiratory therapists (22), and feedback and education concerning lung-protective ventilation (22, 23).

Limitations. The multidisciplinary survey developed in our single-center study may be helpful in evaluating the effect of efforts to reduce organizational and clinician-related barriers to implementation of low tidal volume ventilation for ARDS patients. However, further testing of the survey is required to support these preliminary estimates of reliability and validity and to determine its test–retest reliability and responsiveness to change. Furthermore, the generalizability of findings from this survey is limited by 1) the relatively small sample size from a single hospital site and because 2) the majority (>85%) of ARDS patients are cared for in the medical ICU (which has a low tidal volume ventilation protocol) by internal medicine–trained intensivists. Because of the relatively small sample size of respiratory therapists and nurses working in each ICU, we could not reliably evaluate ICU-level differences in barriers for these provider groups. Further validation as part of a large multicentered study is needed.

CONCLUSIONS

This study identified important organizational and clinician barriers to implementation of low tidal volume ventilation, particularly among nurses and physicians in training. Understanding the barriers to use of low tidal volume ventilation methods using a multidisciplinary perspective is essential to increasing implementation of current research findings and improving outcomes among ALI/ARDS patients. Additional research to further validate the survey instrument and to identify effective methods to overcome organizational and clinician-level barriers to implementation of low tidal volume ventilation is needed.

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Appendix 1. Cronbach's alpha and interscale correlations of each subscale

Scale/Subscale	Overall Provider Barriers Scale	Attitudes Subscale	Behaviors Subscale	Knowledge Subscale	ICU Organizational Barriers Scale
Overall Provider Barriers Scale	**0.91 (0.89 to 0.92)**	—	—	—	—
Attitudes Subscale	0.94[a]	**0.87 (0.84 to 0.89)**	—	—	—
Behaviors Subscale	0.73[a]	0.55[a]	**0.64 (0.56 to 0.71)**	—	—
Knowledge Subscale	0.87[a]	0.69[a]	0.54[a]	**0.78 (0.74 to 0.82)**	—
ICU Organizational Barriers Scale	0.69[a]	0.62[a]	0.57[a]	0.59[a]	**0.78 (0.73 to 0.82)**

ICU, intensive care unit.
[a] $p < .001$. Cronbach's alpha (95% confidence interval) values are in bold type along the main diagonal of the table; correlations between scales/subscales are not in bold type.

Appendix 2. Item-subscale and item-scale Pearson correlations[a]

Subscale	Item	Item-Subscale Correlation	Item-Scale Correlation[b]
Attitudes Subscale	8	.70	.78
	9	.70	.77
	12	.51	.58
	16	.51	.58
	17	.52	.58
	18	.68	.70
	19	.63	.53
	20	.67	.57
	21	.57	.47
	22	.39	.28
Behaviors Subscale	23	.41	.71
	24	.43	.31
	25	.50	.46
Knowledge Subscale	10	.56	.58
	11	.45	.63
	13	.55	.51
	14	.62	.56
	15	.64	.62
ICU Organizational Barriers Scale	26	.51	—
	27	.70	—
	28	.66	—

ICU, intensive care unit.
[a] All correlations have $p < .001$; [b] item correlated to Overall Provider Barriers Scale.

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