Practice Variability in Management of Acute Respiratory Distress Syndrome: Bringing Evidence and Clinician Education to the Bedside Using a Web-Based Teaching Tool

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BACKGROUND: Clinical practice often lags behind publication of evidence-based research and national consensus guidelines. OBJECTIVE: To assess practice variability in the clinical management of acute respiratory distress syndrome (ARDS) and test an evidence-based, online clinician-education tool designed to improve intensive-care clinicians' understanding of current evidence about ARDS management. METHODS: We surveyed 117 intensive care clinicians (16 critical care physician specialists, 28 resident physicians, 50 critical care nurses, and 23 respiratory therapists) with an online questionnaire in our tertiary academic institution. Fifty of the original respondents (12 residents, 26 critical care nurses, and 12 respiratory therapists) also responded to a repeat survey that included context-sensitive hypertext links to a summary of critically appraised primary articles regarding ARDS management, to determine if the responses changed after the clinicians had read the evidence-based summary information. RESULTS: Critical care physician specialists were most likely to choose the low-tidal-volume (low-V_T) ventilation strategy and protocol-based ventilator weaning and were least likely to choose neuromuscular blockade or parenteral nutrition ($p < 0.05$). In a paired comparison, individual respondents were more likely to choose treatment options that are based on stronger evidence (low-V_T, daily interruption in sedation, and protocol weaning [$p < 0.01$]). We also reviewed the medical records of 100 patients who were mechanically ventilated for > 48 h, during the 6 months before and after the survey, from which we identified 45 ARDS patients. Following the clinician-education intervention, ARDS patients were less likely to receive potentially injurious high-V_T ventilation (mean day-3 V_T 10.3 ± 2.3 mL/kg before vs 8.9 ± 1.7 mL/kg after, $p = 0.02$). CONCLUSION: Web-based teaching tools are useful to educate intensive-care practitioners and to promote evidence-based practice. *Key words: evidence-based medicine; ARDS; acute respiratory distress syndrome; decision making, computer-assisted; online systems; education-continuing.* [Respir Care 2004;49(9):1015–1021. © 2004 Daedalus Enterprises]

Introduction

Evidence-based medicine (EBM) is a relatively new medical tool that combines many skills, with the aim of assessing and improving outcomes. These skills include defining a clinical question, conducting a systematic search of the literature to identify pertinent primary articles, and critically appraising the articles to determine the best evidence relating to the clinical question.[1] These skills are not traditionally part of medical training.[2] With a critically ill patient who has complex problems and multiple interventions, EBM may substantially improve outcomes while helping to minimize complications and costs.

Despite considerable progress among critical care physicians in adopting EBM principles, there are still substantial delays between the publication of research evidence and the implementation of that evidence in clinical man-

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agement.[3–6] In the intensive care unit (ICU) multiple practitioners, including physicians, nurses, and respiratory therapists (RTs), form a team to implement the best evidence into practice and optimize patient outcomes. Traditional education methods such as textbooks, journals, and lectures may be limited in their success and usefulness because of ICU clinicians' time constraints.

Widespread access to the World Wide Web makes it an attractive education medium for busy critical care practitioners.[7] Information technology has played a crucial role in the development and implementation of EBM. Powerful Web search engines allow efficient retrieval of information from databases, electronic journals, and online textbooks. Hypertext links in Web documents give immediate access to important details (eg, key figures, abstracts, and conclusions) that had hitherto been buried within large amounts of information. Web documents are easy to update and can include audiovisual enhancements, which are also key elements of information technology.[8] The combination of Web technologies, database storage and retrieval, and the efficiencies of electronic communication may provide attractive learning opportunities in the ICU. These technologies allow all intensive care team members convenient and immediate access to information and utilization of EBM.

The aim of the present study was to evaluate practice variability among critical care team members with regard to their practices in managing acute respiratory distress syndrome (ARDS) and to assess the feasibility and effectiveness of an EBM-based online education tool about ARDS management. We used EBM principles to assess the available evidence and design an online ARDS teaching tool, which we included in the ARDS-management survey. The tool used a familiar Web-based interface and context-sensitive hypertext links to provide critical care team members with instant access to an evidence-based summary of key studies regarding various aspects of ARDS management.

Methods

Our institutional review board approved the protocol. Phase 1 of the online survey (Fig. 1) was designed so that it could be completed within 10 min. Respondents were not required to answer all of the questions. The respondents' preference for the various management options was semi-quantitatively assessed with a multiple-choice answer sheet. The answers were combined into 2 categories for analysis: category I was "almost always" or "frequently" and category II was "almost never" or "rarely." Following completion of the survey all respondents completed a satisfaction rating of the survey.

The survey topics were grouped under 5 headings:

1. Respiratory Care: tidal volumes (V_T), positive end-expiratory pressure, recruitment maneuvers, noninvasive ventilation, hypoxemia and hypercapnia correction, and ventilator weaning modes and weaning protocols
2. Sedation and Paralysis: daily trials off sedation, use of standardized protocols, and "train of 4" monitoring
3. Infection Control: head elevation, central line management, invasive diagnostic strategies for ventilator-associated pneumonia
4. Fluid and Nutrition: use of pulmonary artery catheter, restrictive fluid balance, and total parenteral nutrition
5. Miscellaneous: prone positioning, use of steroids

A hypertext link to the Web-based survey application was distributed via e-mail to all critical care, internal medicine, and anesthesiology physicians in our tertiary care academic institution. Our critical care nurses and RTs were also surveyed. Survey respondents who agreed to take a repeat survey of the same questions were provided with context-sensitive hypertext links to details from a summary of critically appraised primary articles regarding ARDS management. The responses to both the first and second surveys were captured by our Web application and stored in a "structured query language" (SQL) database (Microsoft, Redmond, Washington). The survey responses were given unique identifiers at the time of capture, but the respondent's identities were not known.

Our methodology to create the summary of critically appraised ARDS management articles was based on EBM guidelines. First we searched the National Library of Medicine PubMed database (for the years 1990–2000) for randomized, controlled trials regarding ARDS management. We then reviewed the references in the retrieved articles and ARDS practice guidelines published over the past 5 years, to identify additional information sources. We then critically appraised the selected studies and graded their evidence according to the modified McMaster University criteria adopted by the Society of Critical Care Medicine.[9] Context-sensitive hypertext links linked the summary information within the survey questions.

We evaluated the effectiveness of our clinician-education intervention by reviewing the charts of 100 patients who received mechanical ventilation in the ICU for > 48 hours, during the 6 months before and the 6 months after the intervention. We identified 45 patients who had ARDS as defined by the American-European Consensus Conference on ARDS.[10] Clinical outcomes, mechanical ventilation settings, use of neuromuscular blockade, sedation, total parenteral nutrition, and predicted hospital mortality or actual hospital mortality were then reviewed and compared.

We used the chi-square test for between-group comparisons. Differences were considered statistically significant when $p < 0.05$. No adjustments were made for multiple comparisons.[11] Given the limited number of available crit-

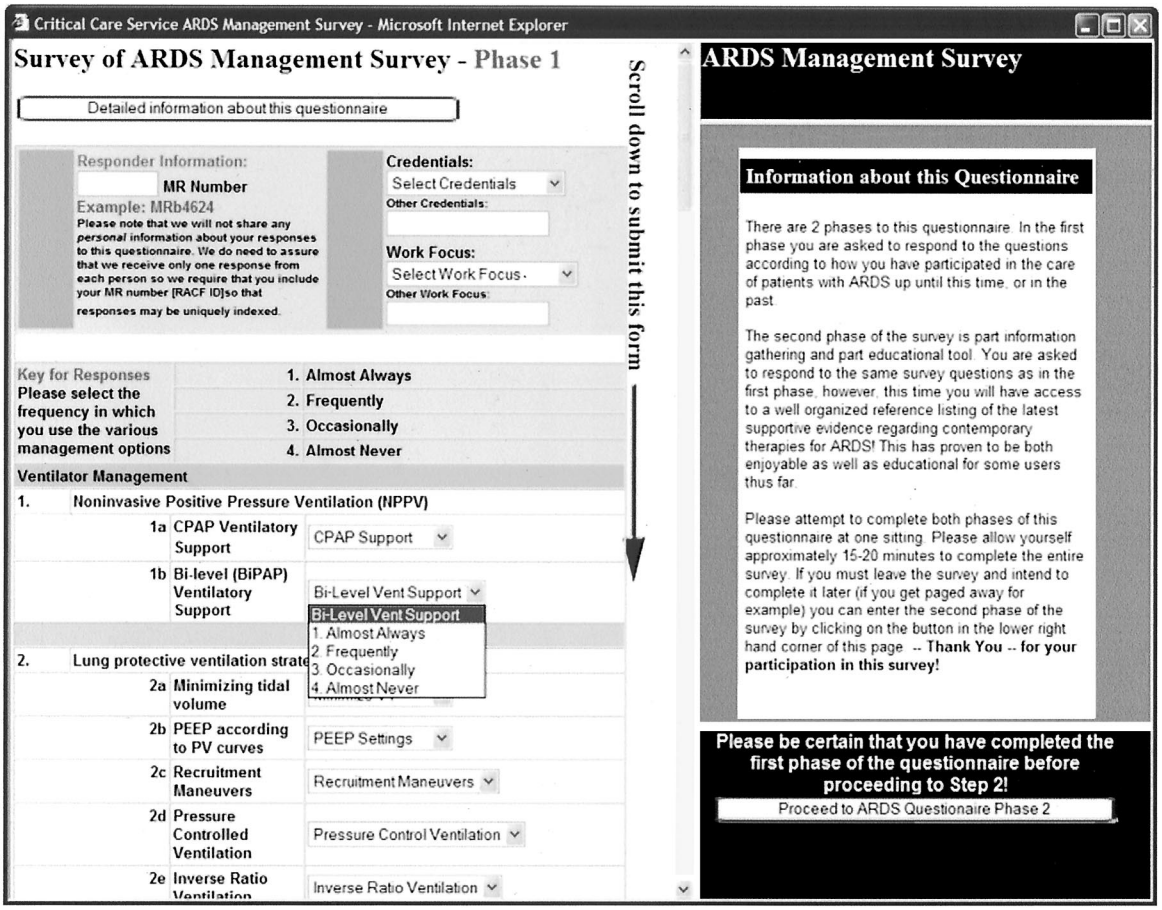

Fig. 1. First page of our first online survey of intensive care clinicians' practices regarding management of acute respiratory distress syndrome.

ical care specialists (we needed a minimum of 15 respondents), we needed at least 20 subjects in each of the other 3 survey groups to detect a moderate-to-large difference in accurate responses ($>$ 85% vs $<$ 40% "successes"), assuming power of 80% and a 1-sided p value of 0.05. We used McNemar's chi-square test for paired comparisons of individual responses before and after the clinician-education intervention. With the 50 clinicians who responded to both the surveys we had 80% power to detect a moderate change in the responses (25% more "successes"). Again, differences were considered statistically significant when $p < 0.05$.

Results

None of the respondents reported having any technical difficulties with the survey or the evidence-based summary application. Ninety-five percent of the respondents indicated that they thought the survey application was a helpful learning tool.

There were 117 respondents (35% response rate) to the initial survey of practice variability: 16 critical care specialists, 28 resident physicians, 50 critical care nurses, and 23 RTs. Not all of the respondents answered all of the questions. The survey responses showed significant differences between the responses of the critical care specialists, the residents, the critical care nurses, and the RTs (Table 1). Critical care specialists were more likely to choose the low-V_T strategy and protocol weaning and were least likely to choose intermittent mandatory ventilation weaning, neuromuscular blockade, or total parenteral nutrition (see Table 1).

Fifty of the initial survey respondents (12 residents, 26 critical care nurses, 12 RTs) completed the repeat survey, which provided context-sensitive hypertext links to a summary of critically appraised primary articles regarding ARDS management. This linked information was made available from within each survey category, and the corresponding summary information was displayed in a window adjacent to the survey questions (Fig. 2), to give the user quick access to the summary information while responding to the repeat survey. The summarized articles addressed various aspects of ARDS management, including ventilatory management, fluid

Table 1. Practice Variability in ARDS Management Across Critical Care Team: Results from Respondents Who Completed First Questionnaire

Management Option	Critical Care Physician Specialists (n = 16)		Resident Physicians (n = 28)		Critical Care Nurses (n = 50)		Respiratory Therapists (n = 23)	
	Positive Responses	(%)*	Positive Responses	(%)*	Positive Responses	(%)*	Positive Responses	(%)*
Respiratory Care								
Low-V_T	16	100	22†	78	19†	38	20	86
High PEEP ($\geq$ 15 cm H_2O)	8	50	0†	0	8†	16	2†	9
Permissive hypercapnia	15	94	20	71	26†	52	12†	52
Recruitment maneuvers	9	56	10	38	11†	22	11	50
Normalizing oxygen saturation	2	12	7	25	18	36	7	30
Noninvasive ventilation	7	50	12	43	24	48	9	39
IMV weaning	4	25	10	40	43†	86	22†	100
Weaning protocol	14	87	13†	50	25†	50	14	66
Sedation and Paralysis								
Daily trial off sedation	10	67	13	50	24	48	NA	
Sedation protocol	10	67	14	52	13†	28	NA	
Neuromuscular blockade	2	13	11†	50	20	40	NA	
'Train of 4" monitoring	13	93	12†	48	33†	66	NA	
Infection Control								
Head elevation	15	100	18†	67	41	82	NA	
VAP invasive diagnosis	4	25	14	50	11	22	NA	
Scheduled CVL change	10	62	23	85	34	70	NA	
Fluid and Nutrition								
Pulmonary artery catheter	9	56	18	67	31	63	NA	
Restrictive fluid balance	10	62	12	46	18	37	NA	
Total parenteral nutrition	7	43	18	69	40†	80	NA	
Miscellaneous								
Late-phase steroids	8	50	7	30	16	32	NA	
Prone positioning	3	19	6	23	7	15	3	13

ARDS = acute respiratory distress syndrome
V_T = tidal volume
PEEP = positive end-expiratory pressure
IMV = intermittent mandatory ventilation
NA = not applicable (respiratory therapists were not asked these survey questions)
VAP = ventilator-associated pneumonia
CVL = central venous line
*Percentages are based on the total number of received responses for each question in this option category.
†$p < 0.05$ via chi-square test, compared to critical care attendings and fellows

and nutrition, sedation and paralysis, infection control measures, and other miscellaneous topics (which included prone positioning and use of late-phase steroids).

After the respondents reviewed the ARDS-management summary links, there were significant changes in their repeat survey responses; interventions that are based on stronger evidence were chosen more frequently (Table 2).

To assess the impact of our intervention on patient care provided in the medical ICU, we reviewed the records of ARDS patients who received mechanical ventilation during the period 6 months prior and 6 months after our intervention. From a sample of 100 patients who were mechanically ventilated for >48 hours, we identified 45 patients who had acute lung injury/ARDS. Their mean age was 62 ± 2.5 y and their mean ratio of P_{aO_2} to fraction of inspired oxygen (P_{aO_2}/F_{IO_2}) was 156 ± 16 mm Hg. Twenty-three of the patients were in the ICU during the 6 months prior to the survey and 22 patients were in the ICU during the 6 months after the survey. Following the clinician-education intervention, ARDS patients were less likely to receive potentially injurious high-V_T ventilation (mean day-3 V_T 10.3 ± 2.3 mL/kg before vs 8.9 ± 1.7 mL/kg after, $p = 0.02$). Between the 2 patient groups there were no significant differences in Acute Physiology and Chronic Health Evaluation III scores (78 ± 5 before vs 83 ± 6 after, $p = 0.62$), day-1 V_T (10.4 ± 0.5 mL/kg before vs 9.8 ± 0.5 mL/kg after, $p = 0.4$), day-3 positive end-expiratory pressure (8.5 ± 1 cm H_2O before vs 9.8 ± 1 cm H_2O after, $p = 0.3$), neuromuscular blockade (30% before vs 32% after, $p = 1.0$), use of total parenteral nutrition (65% before vs 70% after, $p = 1.0$), predicted hos-

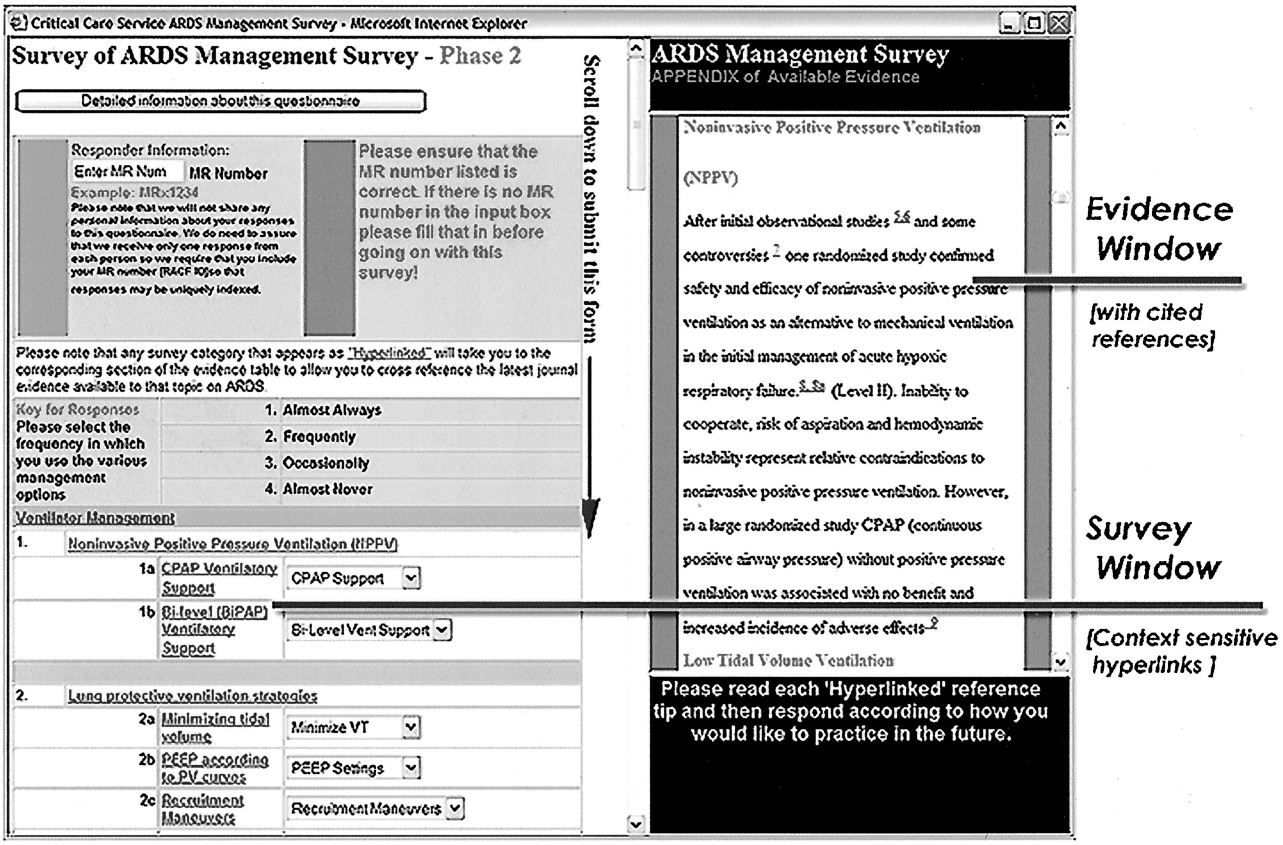

Fig. 2. First page of our second online survey of intensive care clinicians' practices regarding management of acute respiratory distress syndrome.

pital mortality (41% before vs 53% after, $p = 0.18$), or actual hospital mortality (43% before vs 50% after $p = 0.77$). Between the 2 patient groups, only 1 patient underwent intermittent mandatory ventilation before the survey, and none of the patients did after the survey.

Discussion

In the present study we found significant differences in knowledge and practice regarding ARDS management among critical care team members. The survey respondents uniformly expressed satisfaction with the Web-based clinician-education tool, reporting it to be helpful and a desirable way to learn about ARDS management. Although the low overall response rate did not allow us to judge the effectiveness of the teaching tool, it nonetheless appeared to have a measurable education value (see Table 2) and may have contributed to the observed practice changes (Fig. 3).

Several recently published clinical trials could substantially change critical care practice.[12,13] With ARDS the application of such evidence has been delayed. An example is the study that demonstrated that a low-V_T strategy significantly lowers mortality among ARDS patients.[12] However, Rubenfeld et al found that the latter study has not significantly influenced clinical practice (ie, caused clinicians to start employing the low-V_T strategy with ARDS patients) at one of the centers that originally participated in the study.[14–16] There is inter-institution variability in clinicians' beliefs and practices about ARDS management.[16] Although there is still a controversy with regard to how low V_T needs to be to avoid ventilator-induced lung injury, it is clear that high V_T (> 10 mL/kg of ideal body weight) is harmful.[17] Following the clinician-education intervention, the use of potentially injurious high-V_T ventilation became less common at our institution.

Implementing EBM in the ICU is a challenging task.[3,4] Though traditional teaching media such as general practice guidelines and textbooks are largely ignored,[14] interventions supported by local or regional opinion leaders are more likely to be adopted.[4] Computers, e-mail, Internet access, and other communication technologies are now ubiquitous in the ICU. Although computer-based education has numerous applications and tremendous potential, there is little evidence that it has advantage over more

Table 2. Results of 50 Respondents Who Completed Second Questionnaire Comparing Responses Before and After the Clinician-Education Intervention

Management Option	Before (n = 50)		After (n = 50)	
	Positive Responses	(%)*	Positive Responses	(%)*
Respiratory Care				
Low-V_T	29	58	41	82
High PEEP (≥ 15 cm H_2O)	6	12	4	8
Permissive hypercapnia	33	66	39	78
Recruitment maneuvers	20	42	22	45
Normalizing oxygen saturation	18	36	5†	10
Noninvasive ventilation	23	46	27	55
IMV weaning	23	48	34	72
Weaning protocol	36	73	14†	29
Sedation and Paralysis				
Daily trial off sedation	16	39	36†	83
Sedation protocol	18	41	12	32
Neuromuscular blockade	12	30	38†	90
"Train of 4" monitoring	27	63	31	77
Infection Control				
Head elevation	36	84	38	87
VAP invasive diagnosis	8	19	27†	67
Scheduled CVL change	32	72	14†	34
Fluid and Nutrition				
Pulmonary artery catheter	30	66	28	65
Restrictive fluid balance	14	34	27†	64
Total parenteral nutrition	32	76	13†	30
Miscellaneous				
Late-phase steroids	11	24	27†	63
Prone positioning	6	13	13	26

V_T = tidal volume
PEEP = positive end-expiratory pressure
IMV = intermittent mandatory ventilation
VAP = ventilator-associated pneumonia
CVL = central venous line
*Percentages are based on the total number of received responses for each question in this option category.
†$p < 0.01$ by McNemar's chi-square test

traditional teaching methods.[8] However, computers indirectly affect several aspects of medical education, such as enabling literature searches, providing access to full-text articles online, and individualizing the learning experience.[8] Practicing EBM would be extremely difficult without Web technology. Electronic communication technologies allow far better targeted information dissemination than was previously possible. To implement EBM in the ICU the tools need to be user-friendly and easily accessible, and they need to contain relevant, current information with appropriate graphics and context-sensitive hypertext links.

There were several limitations to the present study. It was undertaken in a single center to assess the feasibility of "EBM-inspired" online education in the ICU. One of our original aims was to test our survey and education format and application with a larger group of clinicians from outside of our institution, but institutional concerns regarding information security were an overwhelming obstacle. An independent group or Web site would be the best way to implement and objectively administer a similar electronic survey and to provide a computerized, evidence-based, clinician-education program to a larger group. We selected electronic solicitation and distribution of our survey and clinician-education application only within our institution, and that methodology could potentially bias those in other institutions who do not have widespread access to electronic communication resources or Web access.

The most important limitation of our study was the overall response rate of 35%, which may have been due to confidentiality concerns of staff when participating via electronic media or to the absence of incentives (such as continuing education credit) or a requirement to participate. Consequently, the observed changes in survey responses might not have been caused by our clinician-education intervention. However, at the time of the study, there was no other formal effort to implement the research evidence that our clinician-education application was designed to promulgate and thus no other apparent reason for the observed changes. Finally, because we did not have a control group (who would have undergone conventional education rather than computer-based education), it was impossible to directly compare our online education system to traditional teaching methods.

We demonstrated that Web-based teaching of ARDS management (founded on an evidence-based summary of primary research articles) is feasible and was well received. Larger studies of intensivists and other physicians are needed to investigate the effects of EBM-guided online teaching in the ICU. Another possible application would be to combine information-technology with an ICU disease-severity scoring system such as the Acute Physiology and Chronic Health Evaluation.[15] In such an application, should the severity of a patient's illness exceed a certain

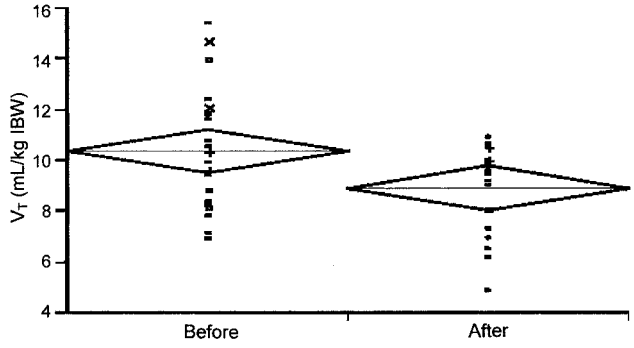

Fig. 3. Tidal volume (V_T) on the third day of mechanical ventilation of patients with acute respiratory distress syndrome in the intensive care unit during the 6 months before and after the clinician-education intervention. IBW = ideal body weight.

score, the clinician's computer would immediately provide hyperlinks to summary information on the best available evidence about managing the patient's condition. Using information technology to communicate evidence-based summaries of primary articles in an integrated Web application would enable all ICU team members to be up to date about which practices have what supporting evidence, and to appreciate the peer-reviewed primary studies behind the techniques used in the ICU.

Conclusions

We demonstrated the feasibility of an evidence-based online teaching tool in the ICU. After the clinician-education intervention the respondents' survey responses were more in agreement with evidence from critically appraised primary literature. Additional studies are needed to compare online teaching to traditional teaching methods in the ICU.

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