Mechanical ventilation in rural ICUs

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Background: In recent years, rural hospitals have expanded their scope of specialized services, which has led to the development and staffing of rural intensive care units (ICUs). There is little information about the breadth, quality or outcomes of these services. This is particularly true for specialized ICU services such as mechanical ventilation, where little, if any, information exists specifically for rural hospitals. The long-term objectives of this project were to evaluate the quality of medical care provided to mechanically ventilated patients in rural ICUs and to improve patient care through an educational intervention. This paper reports baseline data on patient and hospital characteristics for both rural and rural referral hospitals.

Results: Twenty Iowa hospitals were evaluated. Data collected on 224 patients demonstrated a mean age of 70 years and a mean ICU admission Acute Physiology and Chronic Health Evaluation (APACHE) II score of 22, with an associated 36% mortality. Mean length of ICU stay was 10 days, with 7.7 ventilated days. Significant differences were found in both institutional and patient variables between rural referral hospitals and rural hospitals with more limited resources. A subgroup of patients with diagnoses associated with complex ventilation had higher mortality rates than patients without these conditions. Patients who developed nosocomial events had longer mean ventilator and ICU days than patients without nosocomial events. This study also found ICU practices that frequently fell outside the guidelines recommended by a task force describing minimum standards of care for critically ill patients with acute respiratory failure on mechanical ventilation.

Conclusions: Despite distinct differences in the available resources between rural referral and rural hospitals, overall mortality rates of ventilated patients are similar. Considering the higher mortality rates observed in patients with complicated medical conditions requiring complex ventilation management, the data may suggest that this subgroup could benefit from treatment at a tertiary center with greater resources and technology.

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Background

Resources and personnel often limit comprehensive health services in rural areas. Yet, rural hospitals, fueled by community expectations and the need for expanded revenue sources, have expanded their scope of specialized services, which has led to the development of rural intensive care units (ICUs). Despite the growth in number and use of intensive care services [1], there is little information about the breadth or quality of these services in the rural setting [2]. This is particularly true for specialized ICU services such as mechanical ventilation, where no information exists specifically for rural hospitals. (A Medline search performed using the key words ICU, rural hospital and mechanical ventilation produced no similar literature).

Moscovice and Rosenblatt [3] suggest that the ability of rural hospitals to provide specialized services depends on a number of factors, including the training and interests of local personnel, the ability to maintain performance standards despite a small patient volume, the extent of support resources and financial stability. In previous studies involving rural hospitals, there have been quality concerns surrounding the threshold effect, namely that sufficient patient volume may not be available to maintain requisite skills [4,5]. There is evidence that low volumes of specialized services, as frequently occurs in rural hospitals, may result in poorer outcomes [5–7].

The main objectives of our study were, therefore, to: (1) determine the quality of care provided for a specific, low-volume patient population; and (2) improve the quality of care if deficiencies were found.

This report provides a description of the baseline data collected for the 3-year study, including differences found in both institutional and patient variables between rural referral hospitals and rural hospitals with more limited resources. The data reported here form a snapshot of rural ICUs: the patients, institutional characteristics, and practice patterns. These baseline data constitute a necessary starting point for evaluating and improving the care given in these settings.

On the basis of practice variations found during the pilot study, the study design included an educational intervention that would be implemented to assist the rural ICU staff in their efforts to provide quality care. The intervention followed medical record audits and included face-to-face provider feedback, written recommendations, reference articles, seminars and telephone consultations. Specific data describing the impact of patient characteristics and process performance on mortality rates have recently been published [8]. Data describing the specific effects of the outreach educational program on patient care processes and outcomes in the treatment group versus control group have also been published [9].

Methods

Funded by a grant from the Agency for Health Care Policy and Research (AHCPR), a multidisciplinary study team from a major Midwest academic medical center conducted a systematic evaluation of care provided to mechanically ventilated patients in rural ICUs. The study team consisted of a pulmonologist, research nurse, ICU nurse, respiratory therapist, dietician and pharmacist, all with critical care experience.

Seventy-eight hospitals met eligibility criteria: short-stay hospitals located in a Health Care Financing Administration (HCFA)-designated rural county with a critical care unit. Twenty of the 78 eligible rural Iowa hospitals were randomly selected and contacted. All hospitals contacted agreed to participate in the study and share patient and cost information. Enrollment was limited to 20 hospitals because of the extensive burden of data collection and multiple visits required to each participating facility during the 3-year study. The statistical power of the sample size was approved by the AHCPR.

On the basis of HCFA definitions, two major categories of rural hospitals were identified. A hospital qualified as a rural referral hospital (RRH) if it was in a rural area and met specific criteria concerning bed size, referral patterns or case mix intensity. Seven of the 20 participating hospitals qualified as RRH and represented all the rural referral facilities in the state. The remaining 13 facilities enrolled were termed rural hospitals (RH), which had more limited bed capacities and resources.

Hospital demographic characteristics were supplied by each participating hospital. These included ICU size, average daily census, equipment availability, ICU staff, physician mix, and the availability of specialists and support personnel, including respiratory, pharmacy and dietary professionals.

The data collection tool was based on objective indicators established by the Task Force on Guidelines, Society of Critical Care Medicine [10]. Using these indicators as a guide, the university team of ICU specialists developed more specific standards based on current practice (Table 1). Standards were made more specific by establishing strict criteria defining the dose, frequency and time frame within which initiation of treatment was expected; for example, task force guidelines recommended measures such as nutritional support, stress ulcer prophylaxis and deep vein thrombosis prophylaxis. The team clarified these measures and included additional criteria. Team standards required that a complete nutritional assessment including the patient's protein and calorie requirements be documented within 72 h of admission to the ICU. Stress ulcer and deep vein thrombosis prophylaxis was required to be initiated by day 2 in the ICU, and minimum therapeutic levels of treatment were established. The tool reflects basic processes of ICU care that should be delivered regardless of available technological resources. The tool allowed evaluation of processes of care in seven major categories: laboratory assessments, nursing care, stomach ulcer protection, thrombosis protection, dietary management, ventilator management and ventilator weaning.

Patient records were selected for team review by International Classification of Diseases (ICD)-9 procedure codes that reflected the presence of mechanical ventilation (96.72, ventilated for longer than 96 h; 96.71, ventilated for less than 96 h; 96.70, period of ventilation unspecified). The patients most desired for this assessment were those ventilated for longer than 96 h. This longer ventilation period allowed sufficient time to evaluate overall patient care management techniques and practice patterns and assured a more homogeneous group of patients between facilities and across time. In rural hospitals with under 100 beds, few patients met the criteria of ventilation for longer than 96 h. Consequently, in these facilities, the medical records of all patients with ventilation codes were reviewed.

Three categories of patients that would be likely to provide limited evidence of ventilator management techniques were excluded from the study: (1) patients on a

Table 1

Processes of care: standards for patients with acute respiratory failure on mechanical ventilator support

I. Initial laboratory assessment
- a. General screen: phosphate, albumin, calcium, LFTs
- b. Prothrombin time/partial thromboplastin time
- c. Magnesium
- d. CXR
- e. Electrocardiogram
- f. If phosphate or magnesium ≤ 1.0 mg correct level within 24 h

II. Subsequent laboratory assessment
- a. Daily ABG's, CXR first seven days on ventilator
- b. Repeat initial panel at ventilation day 5–7
- c. Repeat magnesium
- d. If phosphate or magnesium ≤ 1.0 mg correct level within 24 h

III. Nursing assessments and care
- a. Daily weights
- b. Intake and outputs every shift and 24 h
- c. Communication with physicians regarding patient condition
- d. Pulmonary care: every 2 h repositioning, semi-fowlers

IV. Stress ulcer (initiate by day two in ICU)
- a. Use of antacids, H_2 blockers, sucralfate or enteral feeding
- b. Monitor gastric pH if antacids of H_2 blockers utilized

V. Thrombus protection (initiate by day two in ICU)
- a. Anticoagulation if no contraindication exists
- b. Thigh-high Ted hose and compression stockings if anticoagulation contraindication exists

VI. Dietary management
- a. Document dietary assessment (protein/calorie requirements) within 72 h
- b. Initiation of feeding with 72 h of ICU admission
- c. Verify NG tube position by auscultation, aspiration or CXR
- d. If enteral feedings held >72 h was alternate supplement initiated

VII. Ventilator management
- a. Initial tidal volume 8–12 cm^3/kg, rate 10–20, A/C mode, 100% FiO_2 (unless prior $PO_2 \geq 60$)
- b. ABG's 30 min after ventilator initiation
- c. Prompt (within 60 min) changes for respiratory alkalosis ($pH \leq 7.52$ with $PCO_2 \leq 35$) and/or respiratory acidosis ($pH \leq 7.30$ with $PCO_2 \geq 55$)
- d. PaO_2 was maintained at ≥ 90% saturation during initial 30 min of treatment
- e. Prompt (60 min) ventilator adjustments for sustained desaturations < 90%
- f. ABG's 60 min after major ventilator changes; Mode, TV by 100, RR by 4 breaths per min unless set ≤ 10, then by 2 breaths per min
- g. Documentation of ET tube size
- h. Documentation ET tube cuff pressure at least daily, ideally every 8 h
- i. Maintain ET tube cuff pressure < 30 mmHg

VIII. Decision to wean
- a. Medical stability (no fever, hypotension, arrhythmias)
- b. Laboratory stability (Hgb ≥ 10, normal magnesium, phosphate >1.0, normal calcium (expect decrease by 0.8 mg/dl for each 1 g/dl decrease in albumin), sodium 130–150, potassium 3–5.5
- c. Optimal sedation (absence of neuromuscular blocking agents)
- d. Weaning parameters
  1. PaO_2 > 55 mmHg on < 50% FiO_2
  2. VE < 12 l/min
  3. Two of the following four: MVV > 2 VE, TV > 5 ml/kg, FVC > 10 ml/kg, or NIF ≤ 20 cmH_20
- e. Documentation of intervention of patient anxiety and/or fatigue
- f. Documentation of attempts to manage patient pain
- g. Successful planned extubation (patient did not require reintubation within 24 h)

Developed by the UIHC multidisciplinary team; data based on [10]. ICU, intensice care unit; A/C, assist control; LFT, liver function test; ABG, arterial blood gas; CXR, chest X-ray; NG, nasogastric; ET, endotracheal tube; RR, respiratory rate; MVV, maximum voluntary ventilation; VE, minute ventilation; TV, tidal volume; FVC, forced vital capacity; NIF, negative inspiratory force; Hgb, hemoglobin.

home ventilator admitted for pulmonary exacerbation or respite care; (2) postoperative patients requiring fewer than 6 h of ventilation while anesthetic agents were reversed; and (3) patients shown to be brain dead shortly after admission but ventilated while treatment and organ donation discussions could be conducted with the family. For patients requiring re-admission to the ICU for ventilator support within the same hospital stay, only the first ventilated period was reviewed.

Data were collected from medical records of 224 patients requiring mechanical ventilation while treated in 20 rural Iowa ICUs between 1992 and 1994. One hundred and eleven patients were managed at RRHs, whereas 113 were managed at RHs. Patient variables included age, sex, primary and secondary ICD-9 diagnoses, severity of illness as measured by Acute Physiology and Chronic Health Evaluation (APACHE) II, medical conditions resulting in difficult or complicated ventilation, admission source (home, emergency room, nursing home, hospital ward, or acute care facility), do not resuscitate (DNR) status, pay class or insurance coverage and discharge disposition (expired, home, skilled nursing facility, intermediate nursing care facility, other hospital and tertiary facility). For those patients transferred to the tertiary setting, the discharge disposition was also evaluated. A list of 10 medical conditions resulting in difficult or complicated ventilation was developed through consensus of a team of critical care specialists. This variable was monitored because the decision to select appropriate patients for tertiary transfer was considered a process of care. The conditions and related definitions are as follows.

(1) Adult respiratory distress syndrome (ARDS) required diffuse bilateral infiltrates, PO_2 divided by FiO_2 < 200 (both required) and, if pulmonary artery catheter was in use, a wedge pressure < 18.

(2) Status asthmaticus with hypercapnea despite adequate ventilation required diagnosis by the contact physician.

(3) Neurologic catastrophe was defined by an acute deterioration in Glasgow coma score without a specific diagnosis for the decline.

(4) Pneumothorax complicating ARDS or status asthmaticus required diagnosis by the contact physician or radiologist.

(5) Multiple organ failure required diagnosis by the contact physician that two or more organs were in failure (respiratory failure was assumed in all patients requiring mechanical ventilation).

(6) Sepsis syndrome with disseminated intravascular coagulopathy (DIC) or coagulopathy required sepsis as defined in Appendix A in nosocomial events and DIC/coagulopathy defined as a drop in platelet count by 25% from baseline and an increase in prothrombin time (PT) or presence of fibrin degradation products.

(7) Ventilation with peak pressures >50 and positive end-expiratory pressure (PEEP) >15 was defined by these parameters.
(8) Complex chest trauma involved documentation of flail chest or multiple rib fractures and cardiac or pulmonary contusions or extensive subcutaneous emphysema or hemothorax.
(9) Failure to wean required diagnosis by the contact physician.
(10) Complex overdose was defined as overdose requiring treatment by dialysis.

Outcome variables included length of stay, ventilation days, nosocomial events, discharge disposition, and survival. Patients with acute respiratory failure are at risk for a number of nosocomial events. Eighteen of these events were described by Pingleton [11] in her work on complications occurring in patients with acute respiratory failure and were incorporated into the data collection tool. A nosocomial event was defined as an event that occurred in the ICU that was not present or incubating at the time of admission. Definitions for each nosocomial event were developed from several sources and established by the review team. Definitions for infectious events were based on the Center for Disease Control (CDC) criteria. Definitions for mechanical events were based on Pingleton's publication, supporting references, criteria utilized by the risk management division at our institution or criteria developed through consensus of the critical care team. Events and associated definitions are provided in Appendix A.

The study protocol was approved by the Internal Review Board of our academic medical center and deemed exempt from the need for informed consent.

Results

Characteristics of rural ICUs

There was no differentiation of intensive care units in the 20 rural hospitals studied. For efficiency, medical and surgical patients were managed in the same ICU. Although the total acute bed capacity varied with each institution, the ICU to acute bed ratios were comparable at 7%. The mean number of acute beds in participating hospitals was 107 (range 29–320 beds), and the mean number of ICU beds was 7.5 (range 3–16 beds). The mean ICU occupancy rate was 53% (range 5–86%).

Characteristics of patients requiring mechanical ventilation in rural ICUs

A total of 224 patients were evaluated. The mean age of patients was 70 years (range 19–95). The male : female ratio was 1 : 1. The mean ICU length of stay was 10.2 days (range 1–61); the mean number of ventilator days was 7.72 (range 1–42); and the mean hospital stay was 15.8 days (range 1–74 days). The mean Apache II score at ICU admission was 22.2 (range 6–39). Thirty-six per cent of the patients died, 27% were discharged home, 20% were discharged to a skilled or intermediate nursing care facility, 9% were transferred to a tertiary care facility and 8% were transferred to another hospital. In the rural setting, 14% of the patients were designated DNR at or before ICU admission, with 36% ultimately designated DNR at some point in their hospital stay. Of the 20 patients transferred to the tertiary setting, 12 (60%) survived.

Table 2

Primary diagnosis of patients admitted to rural intensive care units

Diagnosis	Number (%)
Respiratory	75 (33%)
Bacterial pneumonia	29 (13%)
COPD/asthma	25 (11%)
Acute respiratory infections	6 (2.6%)
Aspiration pneumonia	5 (2.2%)
Respiratory arrest	5 (2.2%)
ARDS	5 (2.2%)
Status asthmaticus	0 (0.0%)
Cardiovascular/circulatory	72 (32%)
Chronic heart failure	24 (11%)
Myocardial infarction	19 (8.5%)
Cardiac arrest	8 (3.6%)
Diseases of arteries; aneurysm	6 (2.6%)
Cerebrovascular; CVAs, ICH	6 (2.6%)
Arrhythmias	5 (2.2%)
Pulmonary circulation; PE, pulmonary heart disease	4 (1.7%)
Digestive	33 (15%)
Cholecystitis, appendicitis, colitis, enteritis	19 (8.4%)
Ileus, obstruction, hernia	8 (3.6%)
Ulcers, inflammatory bowel disorders	6 (2.7%)
Other	44 (20%)
Trauma, overdose	14 (6.2%)
Cancer, neoplasms	8 (3.6%)
Sepsis, infectious diseases	5 (2.2%)
Complex overdose	0 (0.0%)
All others	17 (7.6%)

COPD, chronic obstructive pulmonary disease; ARDS, adult respiratory distress syndrome; CVA, cerebral vascular accident; ICH, intracranial hemorrhage; PE, pulmonary embolus.

One hundred and twenty-five patients (56%) were admitted from the emergency room, 73 (33%) from general wards and 26 (12%) from either an intermediate or skilled nursing facility or other hospital. Patients admitted to the ICU from a hospital ward had a mean length of stay before ICU admission of 1.4 days (±3.5, range 0–29 days).

Primary diagnoses (based on ICD-9 diagnostic codes) of patients requiring ICU admission and ventilatory support are summarized in Table 2. The diagnostic categories included: respiratory, 75 (33%); cardiovascular, 72 (32%); digestive, 33 (15%); and other (20%). Within these major categories, bacterial pneumonia (13%), chronic obstructive

Table 3

Conditions resulting in complicated ventilation and distribution of conditions in rural hospital intensive care units*

Condition	*n* (%)	Mortality
1. Adult respiratory distress syndrome	51 (23%)	27 (53%)
2. Multiple organ failure	33 (15%)	19 (58%)
3. Sepsis syndrome with DIC	30 (13%)	19 (63%)
4. Neurological catastrophe	14 (6%)	9 (64%)
5. Complex chest trauma	11 (5%)	1 (9%)
6. Pneumothorax complicating #1 or #2	10 (4.5%)	6 (60%)
7. Failure to wean	7 (3%)	1 (14%)
8. Persistently elevated peak pressures ≥50 and PEEP≥15	3 (1%)	3 (100%)
9. Status asthmaticus with hypercapnea	0	0
10. Complex overdose (e.g. need for dialysis)	0	0

*One hundred and one patients with one or more high-risk conditions by diagnosis or criteria. DIC, disseminated intravascular coagulopathy; PEEP, positive end-expiratory pressure.

Table 4

Nosocomial events in rural intensive care units

Event	Number	%
Tracheal intubation/self-extubations	49	22
Nosocomial pneumonia	46	21
Ileus/diarrhea	39	17
Arrhythmias	36	16
Gastrointestinal bleed	29	13
Malnutrition	28	13
Fluid overload	15	7
Alterations in hemodynamics	15	7
Bacteremia/sepsis	11	5
Barotrauma	10	4
Pulmonary artery catheter complications	9	4
Acute renal failure	9	4
Psychiatric	9	4
Pulmonary emboli	5	2
Elevated CO_2 during wean	3	1
Pneumoperitoneum with barotrauma	2	0.9
Interstitial fibrosis	2	0.9
Endocrine	1	0.4

Total number = 318 in 224 patients.

pulmonary disease (COPD)/asthma (11%), chronic heart failure (11%), and complicated myocardial infarction (8.5%) occurred most frequently. Cardiac or respiratory arrest precipitated ventilatory care in only 5.8% of instances.

Patients were evaluated for the occurrence of high-risk conditions (HRC) that uniformly result in complicated ventilation. One hundred and one patients (45%) met criteria for one or more of these HRC. The most common conditions were ARDS (23%), multiple organ dysfunction syndrome (MODS; 15%), and sepsis with DIC (13%). Fourteen of the 101 patients with any HRC (14%) were actually transferred to a tertiary care center. Patients with HRC managed at the 20 participating rural hospitals had a 21% higher mortality rate than patients without these conditions ($P=0.001$). Mortality rates within each group are shown in Table 3. Of the 87 HRC patients not transferred, 13 (15%) were designated DNR either before or at the time they met criteria for the HRC, which made tertiary transfer less appropriate.

Patients with acute respiratory failure are at risk for a host of nosocomial events [11]. The events and associated definitions are provided in Appendix A. The frequency of those observed are listed in Table 4. One hundred and forty-two patients (63%) developed one or more such events during their ICU stay. Patients who developed nosocomial events had significantly longer mean ventilator and ICU days. The mean length of ICU stay was 13 days with 10 ventilated days for patients with nosocomial events, compared with 6 ICU days and 4 ventilator days in the group with no events ($P=0.0001$). Patients in both groups had similar age and admission APACHE II scores.

Comparison of RRHs with RHs

The study found several differences between RRH and RH institutions. Although the number of physicians participating in the care of these severely ill patients was similar per number of ICU beds for RRH and RH hospitals, the make up of the physician team was very different. With the exception of one RH, pulmonary specialists were found exclusively in the RRHs. Family physicians, general internists and general surgeons managed most patients in the RH ICUs. A single RH physician typically managed nine or fewer ventilator patients per year and, more commonly, as few as one to four ventilator patients per year. Table 5 shows the highly significant differences found between RRH and RH facilities. Regardless of facility size, very few rural or rural referral facilities provided such technical services as renal dialysis or pulmonary artery catheterization.

RRH patients had longer hospital stays, ICU days, and ventilation days, as well as a greater number of nosocomial events (Table 6). In all probability, the selection preference (patients ventilated >96 h) contributes to these

Table 5

Comparison of rural hospital characteristics by facility type

Variable	RRH mean ± SD	(range)	RH mean ± SD	(range)	*P**
Acute beds	201 ± 62.7	(141–320)	56 ± 16.9	(29–93)	0.0004
ICU beds	12 ± 2.8	(8–16)	5 ± 1.7	(3–8)	0.0004
ICU/acute bed ratio	6 ± 1.6%		9 ± 2.7%		
ICU occupancy rate	67 ± 15.5%	(40–86%)	30 ± 16.0%	(5–57%)	
Staff FTEs					
Physicians	34 ± 8.5	(24–46)	13 ± 5.3	(6–24)	0.0004
Nurses	24 ± 8.9	(14–42)	8.5 ± 3.3	(4–16)	0.0005
Respiratory therapy	13.3 ± 4.4	(7–19)	3.9 ± 1.9	(1–8)	0.0005
Pharmacy	5 ± 2.1	(3–9)	1.7 ± 0.7	(1–3)	0.0004
Dietary	3.3 ± 1.7	(1–7)	1.3 ± 0.7	(0.5–3)	0.0043
Average ventilation (h/month)	877 ± 770.6	(275–2525)	80 ± 76.1	(8–250)	0.0004

*By Wilcoxon Rank Sum procedure (Rosner 1995). RRH, rural referral hospital; RH, rural hospital; ICU, intensive care unit; FTE, full-time equivalents.

Table 6

Comparison of patient characteristics by facility type

Variable	RRH $n = 111$	RH $n = 113$	*P*	(95% CI)
Age	68 ± 12.7	71.8 ± 14.5	>0.05	(–0.19, 6.99)
Gender:				
Male	58 (52%)	53 (47%)		
Female	53 (48%)	60 (53%)		
ICU Apache II	21.6 ± 7.4	22.8 ± 7.1	>0.20	(–0.72, 3.12)
Total hospital days	20.2 ± 13.9	11.6 ± 9.3	<0.0001*	
ICU days	13.2 ± 9.3	7.3 ± 7.0	<0.0001*	
Ventilation days	9.9 ± 6.6	5.5 ± 6.1	<0.0001†	(2.73, 6.07)
Nosocomial events/patient	1.84 ± 1.88	1.1 ± 1.64	<0.01	(0.28, 1.20)
DNR rate	30% ($n = 33$)	42% ($n = 47$)	>0.05	(–0.5%, 24.5%)
Discharge:				
Home	35 (32%)	25 (22%)		
SNF/ICF	19 (17%)	25 (22%)		
Other hospital	8 (7%)	11 (10%)		
Tertiary hospital	11 (10%)	9 (8%)	>0.50	(–5.5%, 9.5%)
Mortality	38 (34%)	43 (38%)	>0.50	(–8.6%, 16.6%)

Values are shown as means ± SD. *Comparison of means using 2 sample independent *t*-test procedure (Bosner 1995); †comparison of proportion rates using two sample binomial test for differences in proportions (Bosner 1995). RRH, rural referral hospital; RH, rural hospital; ICU, intensive care unit; APACHE, Acute Physiology and Chronic Health Evaluation; DNR, do not resuscitate; SNF, skilled nursing facility; ICF, intermediate care facility.

length of stay differences in patient variables between RRH and RH facilities. In the RRH facilities, 101 of the 111 (91%) patients evaluated were ventilated for at least 96 h. In contrast, only 40 of the 113 (35%) patients evaluated in the RH facilities were ventilated for at least 96 h; despite this difference, the mortality rates and tertiary transfer rates are similar in both groups.

Practice variations

Our data collection tool allowed in-depth evaluation of specific patient management techniques. Several practices varied from the guidelines recommended by the task force describing minimum standards of care of critically ill patients with acute respiratory failure on mechanical ventilation [10]. These variations provided an opportunity for

recommendations by the research team. Four examples follow. First, physicians selected an initial ventilator mode that may not have provided adequate support during the period of critical illness. Second, physicians selected minute ventilation too low to allow for adequate rest of the respiratory muscles. Third, mismatches between the set respiratory rate and the patient's respiratory rate were not recognized, potentially prolonging the need for ventilatory support secondary to fatigue of the respiratory muscles. Fourth, the study found delayed responses to abnormal blood gas results, placing the patient at risk for developing arrhythmias or other undesirable physiologic events. Treatment variations were found in both the rural and rural referral setting. Specific data on baseline compliance within each process of care category have been previously discussed by Hendryx *et al* [9].

Discussion

Development of specialized areas of care for the critically ill has occurred in most hospitals in the USA [1,12,13], leading to the growth in number and utilization of ICUs. Despite this growth, there is little information available related to the demographics and quality of rural ICUs [2]. Without specific data on outcomes of rural ICU patient care, it is difficult to evaluate quality of care issues. This lack of data is of particular interest when committees have tried to rationalize and justify regionalization of critical care in rural areas [2,3].

In the rural centers, the emergency room (ER) was the source of admission for 56% of the ICU patients. Escarce and Kelley [14] have suggested that patients admitted to the ICU from the ER often have improved survival rates when compared with patients being admitted to the ICU from other areas. We might anticipate, therefore, that the high percentage of admissions from ERs into rural ICUs could have a favorable impact on survival rates in those ICUs. Undoubtedly, the rural ER has a critical role in providing triage and stabilization of acutely ill patients.

The mean ICU bed occupancy rate of 53% found in all rural hospitals indicates that there was generally an ICU bed available to admit a critically ill patient. ICU bed availability might be an advantage to the rural hospitals by allowing prompt implementation and management of life-sustaining interventions.

Higher mortality rates were found for rural patients with conditions which required complicated ventilation. Mortality rates in rural patients with conditions such as ARDS, MODS, and sepsis with DIC were 53%, 58% and 63%, respectively. These rates are higher than the overall rural mortality rate of 36%. This suggests there are certain high-risk patients who may benefit from transfer to a tertiary care center with greater resources and technology. The significantly higher mortality rates for persons with high-risk conditions suggests that these conditions might serve as primary indicators for evaluating the appropriateness of transferring patients to tertiary care centers.

There are many similarities in demographics and patient characteristics between the small RHs and the RRHs, including mean age, sex, APACHE II score, mortality and the rate of transfer. The most striking differences occur in the variation for lengths of stay in total hospital days, ICU days and ventilator days. This longer length of stay for RRHs cannot be explained by patient record selection alone. In looking for patients ventilated for significant time periods, few were found in the small rural centers. This may indicate that patients with complex medical illnesses, living in counties supported by a small RH may seek acute care and admission from physicians providing services in association with referral centers. This selection process may contribute to the favorable mortality rates for these smaller units. The longer length of stay in the RRHs is likely to have contributed to the higher nosocomial event rate.

Certain limitations of this study need to be acknowledged. First, since the study enrollment was limited to just 20 hospitals, it is not possible to know how representative these were when compared with RHs in other geographic areas. Second, our exclusion criteria eliminated patients requiring only brief periods of ventilation. Had rapidly extubated patients with a good prognosis been included, survival rates might have been higher. Also, exclusion of patients who were ventilated briefly before transfer to another facility may have affected survival rates. Despite these limitations, this study, for the first time to our knowledge, provides information on rural hospital demographics and patient characteristics. These baseline data constitute the starting point for evaluating the quality issues associated with low patient volume. Similar data collection from other rural hospitals in geographically distinct areas may provide the data set required to re-evaluate the opportunities for regionalization of critical care in rural areas. The concept of regionalization for specific diagnoses has been supported by other studies [2,15]. On the basis of the higher mortality rates seen in rural patients with medical conditions resulting in difficult or complicated ventilation, our data seem to support the suggestion by Moscovice and Rosenblatt [3] that success in rural hospitals is best actualized through 'compartmentalization' or the ability to provide only that care which can be performed safely, efficiently and effectively. Early triage and appropriate identification of those high-risk patients who might benefit from transfer to a facility with specialized technology and greater resources may further reduce the mortality currently seen in patients admitted to rural ICUs.

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Appendix A: Nosocomial events

A. Pulmonary complications

(1) *Pulmonary emboli*: clinical diagnosis supported by ventilation/perfusion lung scan, pulmonary angiogram or venous studies.

(2) *Pulmonary barotrauma*: extra alveolar air noted as pneumothorax, pneumomediastinum, subcutaneous emphysema or pneumoperitoneum.

(3) *Diffuse interstitial fibrosis*: development of fibrosis suggested by chest X-ray or computed tomography or documented by open lung biopsy.

B. Complications associated with ventilation and monitoring

(1) *Pulmonary artery catheter*: complications noted with catheter insertion such as pneumothorax, air embolism, or arrhythmias; complications occurring with catheter in place such as pulmonary artery rupture, site infection or thrombosis.

(2) *Tracheal intubation*:
   a. during the intubation; prolonged intubation > 2–3 min;
   b. cannulation of the right mainstem with atelectasis, hyperventilation, or pneumothorax;
   c. During the course of intubation; mechanical dysfunction, cuff leak associated with abnormal arterial blood gases (acidosis = pH ≤7.3 with PCO_2 ≥55 or alkalosis = pH ≥7.52 with PCO_2 ≤35), or S_aO_2 drop < 90%;
   d. tracheal stenosis and
   e. self extubation;
   f. after removal of endotracheal or tracheostomy tube; cuff related injuries, vocal cord damage, erosion;
   g. Trache stoma bleeding and/or blood in secretions, associated with a drop in hemoglobin > 1 g/24 h.

C. Gastrointestinal complications

(1) *Pneumoperitoneum*: free air in peritoneal cavity associated with barotrauma.

(2) *Alterations in gastric motility*: ileus or diarrhea (3–5 stools per day ≥2 days).

(3) *Gastrointestinal bleeding*: defined as the occurrence of frank blood or coffee ground aspirate from the nasogastric tube, melena, a drop in hemoglobin > 1 g/100 ml/24 h, confirmation of bleeding by endoscopy, or three consecutive positive tests for occult blood in stool. Repeat events in same hospital stay excluded.

D. Renal complications

(1) *Acute renal failure*: defined as an abrupt decline in renal function manifested by a rise in serum creatinine greater than 0.5 mg/dl per day or a fall in urine output of less than 400 l/day.

(2) *Positive fluid balance*: Chest X-ray with worsening of infiltrates, or pulmonary edema accompanied by either 1 kg weight gain in 24 h or intake > output by 1000 cm^3 in 24 h. Calculate by intake (not blood), minus urine, minus drainage, minus insensible loss (360 cm^3). If ventilator has humidification; add 300 to intake. This criterion should not be applied to patients in shock, chronic heart failure, or ARDS.

E. Cardiovascular complications

(1) *Alterations in hemodynamics*: documentation of pulmonary hypertension, increased pulmonary vascular resistance, or left ventricular dysfunction by pressure and cardiac output measurements. Any one of the following: pulmonary artery pressure > 40 systolic, wedge pressure > 18, cardiac index < 2.

(2) *Arrhythmias*: documentation on electrocardiogram or rhythm strips of significant ventricular arrhythmias or heart block. Include only events that require medical therapy, cardioversion or pacing.

F. Infectious complications

(1) *Nosocomial pneumonia*: defined as those infections diagnosed after the first 48 h of a patients hospitalization, neither present or incubating at admission, or meeting CDC criteria.

(2) *Bacteremia or sepsis*: bacteremia defined as the presence of viable bacteria in the blood. Sepsis defined as the systemic response to infection, manifested by two or more of the following conditions as a result of infection: (1) temperature $>38^{\circ}C$ or $<36^{\circ}C$; (2) heart rate >90 beats per minute; (3) respiratory rate $>$ 20 breaths per minute or $PaCO_2$ <32 mmHg; and white blood cell count $>12000/mm^3$, $<4000/mm^3$, or $>10\%$ immature (band) forms.

G. Nutritional complications

(1) *Malnutrition*: weight loss of $>10\%$ body weight (from admission weight).

(2) *Elevated CO_2 production during weaning attempts*: patients pCO_2 exceeds 50 mmHg. Patients caloric and carbohydrate count will be reviewed (patient must be free from fever, chills, shivering, or hyperdynamic state). For COPD patients; pCO_2 must exceed baseline by 15%.

H. Other

(1) *Endocrine*: evidence of thyroid or adrenal dysfunction.

(2) *Psychiatric*: anxiety, depression, confusion, sleep deprivation, organic brain syndrome, or psychosis.