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Benchmarking Mechanical Ventilation Services in Teaching Hospitals

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The purpose of this investigation was to examine the technical efficiency of mechanical ventilation nonsurgery (DRG 475) among University Hospital Consortium (UHC) hospitals that consists of volunteer, teaching hospitals across the nation. The data for this study was retrieved from the 1997 UHC database that includes charge and discharge information for 69 hospitals. Data on 7961 patients classified with mechanical ventilation were aggregated to the hospital level. We retained data from a total of 62 hospitals, the other seven hospitals had missing data. The research questions were (1) Do UHC hospitals differ significantly in their efficiencies in the treatment of mechanically ventilated patients? (2) What inputs and outputs contribute most to the inefficiencies associated with mechanical ventilation? Of the 62 hospitals analyzed using data envelopment analysis technique, 10 were considered efficient and 52 were inefficient as compared to their benchmark peers. Efficient and inefficient hospitals did significantly differ between the transferred output variable and between the respiratory, laboratory, and radiology input variables. All inputs demonstrated excessive resource utilization among inefficient hospitals as compared to efficient hospitals. A total reduction of about $19 million dollars in ancillary services would need to occur for inefficient hospitals to approach the frontier of efficient hospitals. This study demonstrates that mechanical ventilation is costly, yet the specified ancillary services are capable of being reduced yielding technical efficiency as demonstrated by 10 efficient hospitals.

KEY WORDS: mechanical ventilation; data envelopment analysis; cost effectiveness.

INTRODUCTION

Health care costs have been increasing over the last 30 years. In 1960, the cost of health care was close to $26 billion and constituted 5% of the gross national product. In 1994, the total cost of health care had risen to $950 billion and 14% of

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the gross national product. Advances in medical technology partially accounted for this enormous increase in health care costs. These advances included the advent of intensive care units and "high-tech" treatments such as mechanical ventilation. In the early 1990s, intensive care costs and mechanical ventilation were estimated at approximately 28% or $47 billion of the total hospital costs.[1]

Mechanical Ventilation

One reason for the increase in intensive care charges resulting in drastic, surmounting hospital charges is the advent of mechanical ventilation. Mechanical ventilation is a means of providing external breathing support to people who have ineffective gas exchange of oxygen and carbon dioxide due to a variety of causes: pneumonia, respiratory failure, chest trauma, and neurological damage just to name a few. Negative pressure devices were first used in the 1930s, and recently in the 1960s and 1970s engineering refinements produced easily accessible positive pressure ventilators. Additional developments including the automation of blood gases and enhanced understanding of ventilation physiology aided the widespread utilization of mechanical ventilation.[2]

Another reason for increased cost associated with mechanical ventilation is because the length of time a patient requires mechanical ventilator support varies. An individual may require short-term mechanical ventilation assistance ($\leq$2 days) or long-term mechanical ventilation ($\geq$3 days) depending on the patient's severity of illness, preexisting health status, and age. Regardless of the reason for mechanical ventilation, morbidity and mortality are associated outcomes. The complication of pneumonia when someone is mechanically ventilated in intensive care ranges from 10–65%,[3–7] adds as much as 10 additional days, increases mortality rates by as much as 55%, and adds billions of dollars to health care costs.[7–10]

Mechanical ventilation is a necessary, yet costly therapeutic modality for patients who need additional mechanical assistance to breathe. Because of this technical intervention, multiple resources are required to monitor the patients' health status while on a ventilator, and this drives up the resource utilization. Consequently, the increase in auxiliary services exponentially increases the cost of hospitalization.

Resource Utilization and Financial Consequences of Mechanical Ventilation

Resource utilization enormously increases hospital costs. Oye and Bellamy[11] found that a small group (8%) of medical ICU patients accounted for a large proportion (50%) of resource utilization. Similarly, Chelluri *et al.*[12] found 19% that of the elderly population studied were responsible for 51% of all hospital charges in their age category. Fein *et al.*[13] also reported congruent findings of a few surgical ICU patients (9%) were responsible for 49% of patient-days. These studies demonstrate a high percentage of resource utilization among a small amount of patients who have high severity needs requiring mechanical ventilation. The intensive needs of mechanically ventilated patients drives up the cost of health care. An increasing cost in health care has resulted in the need to further evaluate the services needed when a patient requires mechanical ventilation.

Kurek *et al.*[14] evaluated clinical and economic outcomes of mechanically ventilated patients in New York State during 1993. They analyzed 10,473 mechanically ventilated patients who were age $\geq$18 years old and discharged in 1993. The average statewide Medicaid reimbursement was $21,578 per discharge. Witek *et al.*[15] reported that out of 100 consecutive patients admitted to intensive care units requiring mechanical ventilation, the variability of length of mechanical ventilation was 1–28 days. Additionally, the hospital charges averaged $10,968 per patient with 20% of the overall hospital charges being attributed to respiratory services. In another study which evaluated 95-nonsurgical Medicare patients requiring $\geq$3 days of mechanical ventilation, the average cost of care was $38,464 which reduced to be $1495/day. The cost of ventilator treatment and associated pulmonary services (respiratory therapy, arterial blood gases, chest radiographs, chest physical therapy, and bronchial treatments) averaged $439.00 per day.[16] The Mayo Clinic Group conducted a study of 150 medical and surgical patients who required mechanical ventilation >2 days and found that the average per-patient cost was $31,896 with average total charges of $47,391 which reduced to $1651 per day.[17] These studies illustrate the high cost of mechanical ventilation services.

A limitation of these studies is that either cost and/or charges were reported resulting in difficulty in drawing interpretive comparisons among the studies. Additionally, the studies were conducted in the late 80s and early 90s, and one would expect the current associated cost of mechanical ventilation to be much higher in the late 90s due to inflation and the cost of advances in treatment. Additionally, hospital efficiency was not measured in any of the studies evaluating mechanical ventilation.

It is evident in these studies that resource utilization among mechanically ventilated patients is enormously high. Because of the increasing cost of health care associated with mechanical ventilation, there is a need to assess the technical efficiency associated mechanical ventilation by benchmarking teaching hospital practices. This is the first study to evaluate the benchmarking practices of mechanical ventilation services in teaching hospitals by using data envelopment analysis (DEA) as method of analysis.

Purpose of Study

Realizing that health care costs associated with mechanical ventilation are rapidly increasing, an incentive exists to identify the technical efficiency associated with high resource utilization during mechanical ventilation in order to facilitate administrative decisions in allocating of critical resources in health care institutions. The focus of this paper is to measure and compare the technical efficiency of mechanical ventilation among teaching hospitals in the University Health Consortium (UHC) by using DEA techniques. This analysis technique identifies efficient and inefficient practices among peer hospitals, and will provide an understanding, for those inefficient hospitals, how to better make organizational decisions to decrease the enormous cost related to resource utilization associated with mechanical ventilation. Immediate incentives exist not only to identify care measurements, but also to identify efficient measures of care of mechanically ventilated patients because of the associated comorbidities and enormous cost.

The research questions in this study are:

1. Do UHC hospitals differ significantly in their efficiencies in the treatment of mechanically ventilated patients?
2. What inputs and outputs contribute most to the inefficiencies associated with mechanical ventilation?

METHODOLOGY

Data

The data for this analysis was obtained from the 1997 UHC database that included 69 teaching hospitals that volunteered to participate in a national university hospital consortium. First, data cleaning procedures of the UHC data were conducted. A total of seven records were deleted due to missing data, leaving 62 UHC hospitals for analysis. The sample evaluated included all patients admitted to any of the 62 UHC hospitals during 1997 who were mechanically ventilated (Table I). Patient level information was extracted based on mechanical ventilation coding (DRG 475) and identified inputs and outputs, then the data were aggregated to the hospital level. There were a total of 7961 patients who had minor procedure revenue coding (respiratory, laboratory, pharmacy, and radiology) based on mechanical ventilation. These records were collapsed to the hospital level so resource utilization comparisons between hospitals could be made by DEA techniques.

Sample

The patient sample almost equally consisted of a mix of gender (males = 4428, 56%) and were primarily white (4925, 62%), and had a median age of 48 (range

Table I. Patient Characteristics

	Frequency	Percent (%)
Gender		
Male	4428	55.6
Female	3533	44.4
Race		
White	4925	61.9
Black	1904	23.9
Other	1132	14.2
Complications		
No substantial complications	425	5.3
Moderate complications	1137	14.3
Major complications	5994	75.3
Missing value	405	5.1
Discharge status		
Home	4124	51.8
Transfer	1566	19.7
Expired	2271	28.5

1–100). The majority of the patients did have a severity classification of major complications (5994, 75%); however, most of the sample was discharged home (4124, 52%). An alarming number of patients requiring mechanical ventilation did expire (2271, 29%) which does support the research findings of high comorbidities and mortality related to mechanical ventilation. The bed size of the UHC hospitals ranges from 107 to 1273 with an average bed size of 538.

Method of Analysis

This investigation employed DEA techniques as a benchmarking technique to assess mechanical ventilation efficiency on UHC hospitals. DEA is a nonparametric linear programming technique that has no assumptions about the form of production function. DEA measures relative efficiency by the ratio of total weighted output to its total weighted input.[18] DEA allows each decision-making unit (DMU) to select any weights for each input provided that the weight is only positive and is universal.

DEA addresses the limitations associated with ratio analysis and regression. Additionally, DEA uses multiple outputs and multiple inputs to identify efficiencies, inefficiencies, and projections of how inefficient DMU can become more efficient by identifying best practice. A best-practice function can be built empirically from observed inputs and outputs.[18] The idea of DEA is to project a frontier estimating technical efficiency for each DMU, in this case a peer group of teaching hospitals. DEA calculations maximize the relative efficiency score of each DMU. The objective is to establish norms of best achieved practice so hospitals that fall short of the frontier can aspire to reach the frontier by modeling the practice patterns of those hospitals on the frontier. This study uses a variable returns to scale (VRS) DEA model in examining the technical efficiency of teaching hospitals with respective mechanical ventilation. The type of orientation of the DEA model means specification of the type of strategy that must be used to enhance efficiency. Since managers of mechanical ventilation facilities can be assumed to have more opportunities to reduce the inputs used to produce patient outputs than discretion over increases in patient outputs, an input orientated model was used.

An input-oriented VRS DEA model to compute efficiency scores can be expressed in the following linear programming problem adapted from Cooper *et al.*:[19]

$$\text{Maximize } E_o = \frac{\sum_{r=1}^{s} u_r y_{ro} + c_o}{\sum_{i=1}^{s} v_i x_{io}}$$

$$\text{Subject to: } \quad \frac{\sum_{r=1}^{s} u_r y_{ro} + c_o}{\sum_{i=1}^{s} v_i x_{io}} \leq 1 \quad u_r \geq 0; v_i \geq 0$$

where E_o denotes the efficiency score for each facility in the set of $o = 1, \ldots, n$ facilities, y_{ro} the selected output r produced by each facility in the set o, x_{io} the selected input i used by each facility in the set o, y_{rj} the selected output r produced by facility j, x_{ij} the selected input i used by facility j. In this formulation, u_r and v_i are the weights assigned respectively to output r and input i, both obtained from DEA. The constant is represented by c_o.

Hospitals have long been characterized as multiproduct organizations in many studies of hospital efficiency.[20,21] Because DEA is particularly well-suited to multiple output organizations, it has had several applications in the health care industry. For example, DEA has been used in nursing homes,[22,23] community mental health centers,[24] Veterans Administration medical centers,[25,26] teaching hospitals,[27] and community hospitals.[28–32] Ozcan[33] summarized the settings and DEA measures in the literature used to measure hospital efficiency. On the basis of the studies related to DEA analysis in the health care environment, DEA will be used to identify benchmarking mechanical ventilation services among UHC teaching hospitals.

Variables

The unit of analysis or the DMU is hospitals. Various inputs and outputs used to compute technical efficiency were aggregated at the hospital level. The review of literature produced more than 20 potential measures of hospital input/output, but most investigators applied similar groups of input/output variables to calculate the efficiency. Input measures most frequently used were assets, labor, and other operational expenses. Inpatient discharge, outpatient visits, and teaching were mostly used as output variables. According to Ozcan,[33]the selection of particular input and output variables could create sensitivity in the results of efficiency variables. In addition, the number of input and output variables can also generate surprising results in DEA analysis. Using too many variables will capture various aspects of the service process and can bias the efficiency scores upward. Therefore, most hospital studies applied 10 or less total input and output variables.[33]

This study evaluated a total of seven variables: four input and three output variables. Two different models were analyzed based on different outputs employed while maintaining the four constant inputs. The two models were evaluated to determine sensitivity because it was undeterminable prior to analysis which model would better reflect quality of mechanical ventilation: ventilator patient days or adjusted discharges.

Input Variables

Four inputs were used in the DEA analysis: respiratory, pharmacy, laboratory, and radiology. Respiratory, pharmacy, and laboratory resources were chosen as input variables because they have been identified as cost-consumptive resources related to mechanical ventilation.[16] Additionally, mechanically ventilated patients require multiple pharmaceutical therapies to provide comfort, promote adequate nutritional status, maintain hemodynamic stability, and treat complicating diseases while on a mechanical ventilator. According to studies and experts, these four inputs capture the resources that hospital administrator can influence related to mechanical ventilation.

Output Variables

Two models with differing outputs were analyzed. Model 1 was initially chosen because ventilator inpatient days, otherwise known as inpatient length of stay, are generally thought to be a midlevel output which is a widely acceptable measure of quality of care among mechanically ventilated patients. Additionally, the frequent reporting of length of stay is of common interest. Therefore, Model 1 which utilized ventilator patient days as a measure of average length of stay as an output variable was analyzed.

However, an additional model (Model 2) was considered because discharge is a frequently used output variable in DEA studies of hospital efficiency. Although discharge as an output of mechanical ventilation was not thought to be a deterministic variable of efficiency, these two models were analyzed to determine which one was more significant based on the same inputs, yet different outputs.

The output variable for Model 1 (Ventilator Patient Days) is inpatient average length of stay. Ventilator patient days was operationalized as average length of stay adjusted inpatient discharges to home, 1/transferred, and 1/expired. Hospital case mix index was used to adjust inpatient discharges. The inpatient discharge was operationalized as home discharge, 1/transferred discharge, and 1/expired. This characterization approximates hospital service quality for the outputs. For those patients who discharged to home represent high quality, and those patients who required transfer to another organization or expired represent lower quality.

In DEA models, output variables should reflect the same characteristics or changing direction. Therefore, 1/transferred discharge and 1/expired were applied instead of transferred discharge and expired, respectively to indicate the similar direction of quality.

While inpatient discharge was the common use of output in DEA hospital studies, patient days can be seen as an intermediary product leading to a discharge. Ehreth[30] pointed out that patient days do not specifically address the hospital's objective to improve health. We argue that for mechanically ventilated patients, ventilator patient days as a measure of length of stay may be a more powerful measure of output than discharge data.

Sensitivity of Model 1 Compared to Model 2

Model 1 and Model 2 are related because each contains the same input variables. These input variables were thought to be consistent for mechanical ventilation regardless of output variables. Sensitivity analysis was conducted to differentiate which model based on the dissimilar outputs was a stronger predictor of quality and efficiency of mechanical ventilation. Table II provides an operational definition of the various variables described in both models of the study.

It is worth to reemphasize that input-oriented DEA model was used in the analyses. The input orientation assumes that hospitals have little control over outputs that in this case refers to the number of patients discharged to home, transferred to other health care organizations, and expired. It is more appropriate to direct

Table II. Variables

Variable	Description
Outputs	
Model 1: Patient ventilator days	Average length of stay adjusted inpatient discharges
Home	Patients discharged to home
Transferred	Patients transferred to another facility
Expired	Patients who died
Model 2: Adjusted discharges	Hospital case mix index adjusted inpatient discharges
Home	Patients discharged to home
Transferred	Patients transferred to another facility
Expired	Patients who died
Input resources	Minor revenue coding of UHC defined subgroups within departmental classifications
Respiratory	Charges for respiratory services and inhalation services
Pharmacy	Charges for drugs and IV solutions
Lab	Charges for chemistries and pathologic diagnostics
Radiology	Charges for chest x-rays and various other radiological procedures

Note. Both models use the same group of input resources.

discussion to inputs where hospitals do have control over utilization of resources for mechanically ventilated patients.

RESULTS

This section includes the analysis of the data, and explains the efficiency relationships among hospitals that treated mechanically ventilated patients. Descriptive statistics are introduced first to illustrate the sample.

Descriptive Statistics

Descriptive statistics for output and input variables are presented to describe the sample in Table III. The outputs reveal that the average patient ventilator days for those who discharged home per hospital was about 800 days, with a standard deviation of 508.55. Under the inputs, radiology ($2,053,000) was the least costly utilized resource, and lab ($8,089,000) was the most expensive. Respiratory ($7,434,000) and pharmacy ($7,242,000) services were equally utilized as depicted by similar averages and standard deviations. The average cost of the services required when a patient requires mechanical ventilation is alarming. Respiratory and pharmacy charges are about $60,000 and lab is above $65,000 per case.

Efficiency Findings

Analysis of the 62 UHC hospitals shows that there is practice variation among the utilization of resources for respiratory, pharmacy, laboratory, and radiology services (Table IV). In Model 1, only 10 (16.13%) of the 62 hospitals were efficient. The remaining 52 (83.87%) were classified as inefficient when compared to efficient hospitals. The reason for the high degree of inefficiency is represented in the slacks.

Table III. Descriptive Statistics of DRG-475 Sample ($n = 62$ hospitals)

	Mean (SD)
Outputs (patient episode/hospital)	
Model 1 : Patient ventilator days	
Home	800.860 (508.555)
Transferred	1.152 (2.527)
Expired	0.487 (0.412)
Model 2 : Adjusted discharges	
Home	101.49 (60.63)
Transferred	0.027 (0.026)
Expired	0.059 (0.114)
Inputs (resource use/$10,000)	
Respiratory	76.797 (49.753)
Pharmacy	75.335 (52.511)
Laboratory	84.148 (68.649)
Radiology	21.336 (17.052)
Average charge (in $ per case)	
Respiratory	$59,810.00
Pharmacy	$58,670.00
Laboratory	$65,530.00
Radiology	$16,620.00

Inefficient hospitals consisted of 34 hospitals which had more patients transferred to other health care organizations and 23 hospitals which had higher number of expired patients.

Additionally, inefficient hospital charges were over $81,000 in respiratory services, $151,400 more in pharmacy services, $140,600 additional charges in laboratory services, and over $84,400 in radiology services as compared to efficient hospitals. Also, the total inefficiencies provide information about the difference between projected and measured data. By evaluating the total inefficiencies, inefficient hospitals are on average expected to decrease $530,000 in respiratory charges, $570,0000 in

Table IV. Efficiency Results ($n = 62$ hospitals)

	Model 1 : Patient ventilator days		Model 2 : Adjusted discharge	
Efficiency		10 (16.13%)		7 (11.29%)
Inefficiency		52 (83.87%)		55 (88.71%)
	n	Mean (SD)	*n*	Mean (SD)
Variables				
Efficiency				
Efficients included	62	0.527 (0.275)	62	0.491 (0.269)
Efficients excluded	52	0.436 (0.197)	55	0.426 (0.210)
Total inefficiency (for inefficients)				
Output				
Home	0	0 (0)	0	0 (0)
Transferred	34	0.019 (0.025)	44	0.065 (0.064)
Expired	23	0.017 (0.018)	39	0.041 (0.046)
Input				
Respiratory	52	53.07 (49.31)	55	55.42 (51.38)
Pharmacy	52	57.78 (38.81)	55	59.85 (45.86)
Laboratory	52	63.62 (61.13)	55	62.82 (59.88)
Radiology	52	14.74 (13.74)	55	15.22 (14.13)

Table V. Performance by Efficient and Inefficient Hospitals Model 1—Patient Ventilator Days

Variables	Mean (SD)		p value
	Efficient ($n = 10$)	Inefficient ($n = 52$)	
Output variables			
Home	694.180 (547.751)	821.375 (503.719)	0.473
Transferred	0.017 (0.018)	0.005 (0.003)	0.054
Expired	0.006 (0.006)	0.003 (0.002)	0.115
Resource utilization			
Respiratory	43.225 (53.819)	83.253 (59.126)	0.051
Pharmacy	49.217 (71.631)	80.357 (47.256)	0.085
Laboratory	41.319 (42.725)	92.384 (69.899)	0.03*
Radiology	8.167 (4.890)	23.868 (17.408)	0.0001***

*$p < 0.05$; ***$p < 0.001$.

laboratory charges, $630,000 in radiology charges, and almost $150,000 in pharmacy charges before reaching the benchmark of their efficient peers (see Table IV).

A two-tailed *t* test with the assumption of unequal variances was conducted to compare the means of the output and input variables between both efficient and inefficient hospitals. There was a significant difference on transferred home, respiratory, laboratory, and radiology between efficient and inefficient hospitals. Inefficient hospitals had significantly more patients transferred to other organizations than efficient hospitals do. Inefficient hospitals also utilized significantly more resources than the efficient hospitals (Table V).

Results of Sensitivity Analysis

Substitution of adjusted discharges in lieu of patient days showed a significant impact on the average efficiency scores. The efficiency score of the two models are highly correlated with a correlation coefficient score of 0.89. Compared to Model 1, there are 70% of the hospitals remained at the original frontier in Model 2. This suggests that patient days is an alternative, a finer measure of adjusted discharges in hospital DEA studies for certain patient groups (Table VI).

In summary, there is a pattern of excessive charges, resource consumption, among inefficient hospitals. For each patient who utilizes mechanical intervention, the respiratory and pharmacy charges are about $60,000 and lab is over $65,000. In order to be efficient, inefficient hospitals, on average, need to reduce 5.3 million dollars in respiratory services, 5.7 million dollars in pharmacy, 6.3 million dollars in laboratory, and 1.4 million dollars in radiology. This data suggests the need for critical evaluation of organizational improvement possibilities to decrease the enormous

Table VI. DEA Sensitivity Tests

	Model size	Pearson correlation	Percentage remained at original frontier	
Model 1 vs. Model 2	7,7	0.892***	70%	*t* test ns

Note. ns = nonsignificant.
***$p < 0.001$.

consumption of services for mechanical ventilation among inefficient hospitals as compared to efficient hospitals.

DISCUSSION

The descriptive statistics of UHC resource utilization confirm the fact that mechanical ventilation is costly. Our study found that the respiratory and pharmacy charges for mechanically ventilated patients are about $60,000, and lab is above $65,000. Secondly, UHC hospitals differ significantly in their efficiencies in the treatment of mechanically ventilated patients. Of 62 UHC hospitals, 16.13% were efficient. Thirdly, inefficient hospitals consume more resources than efficient hospitals. On average, inefficient hospitals charge 5.3 million dollars more in respiratory services, 5.7 million dollars more in pharmacy, 6.3 million dollars more in laboratory, and 1.4 million dollars more in radiology, than efficient hospitals do. The reason why inefficient hospitals used such enormous amounts of resources should be further evaluated at the patient level. Several areas of further investigation include exploring differences in hospital ownership and evaluating mechanical ventilation with surgery (DRG 474), and then combining the two groups of mechanically ventilated patients, those with and without surgery, for comprehensive information about mechanical ventilation.

All inputs (respiratory, pharmacy, laboratory, and radiology) in this study have the potential of being reduced. Further investigation of resource consumption at the patient level would provide more information about the exactness of what type of resources are utilized in order to determine why respiratory services were significantly higher among inefficient hospitals.

Regarding differences between efficient and inefficient hospitals, hospital ownership should be considered. Hospitals may significantly differ between private and public ownership. Secondary analysis of HMOs would be beneficial information to know and to be able to evaluate the number of HMOs in efficient and inefficient hospitals.

Because the sample from the data file only included mechanical ventilation nonsurgery patients and not mechanical ventilation with surgery (a tracheostomy), the resource utilization for the care of all mechanically ventilated patients would be higher. Mechanical ventilation with surgery was not included in the current analysis because the inclusion of a surgical procedure would contribute to the severity of the patients, making it difficult to clearly understand the associated charge of being mechanically ventilated due to a medical reason. Further research about mechanical ventilation with and without surgery is warranted to comprehensively understand technical efficiency related to mechanical ventilation.

In future studies, different outputs and inputs could be used to evaluate whether the current efficient hospitals remain efficient. A sensitivity test showed that patient days, as an output measure, is a proxy for adjusted discharge in hospital DEA studies for certain diagnostic groups. Also, hospitals not in the UHC databank could be reviewed and compared to UHC hospitals and differences between the hospital types based on technical efficiency could be identified. The purpose of further analysis of technical efficiency would be to enable hospital administrators to develop strategies and make decisions about cost reduction of associated mechanical ventilation services.

Reduction Strategies

One strategy for inefficient hospitals would be to avoid redundant services in the hospital or even between a network of corporately owned hospitals. Also, consolidation of resources between facilities needs to be considered. If hospital A and hospital B were both privately owned by the same firm and both provided full services in pulmonary care, services would be duplicated. The administrators of both hospital A and B would need to consider the cost-effectiveness of one of the two hospitals specializing in pulmonary care including mechanical ventilation. Thus, resources would immediately be reduced because the capital budget could be decreased. Consolidating services has been a successful means of decreasing cost as demonstrated by not all hospitals providing birthing services anymore.

Additional cost-cutting strategies may include interdisciplinary management of patients with mechanical ventilation because it would clearly communicate the plan of care among the team and prevent duplication of tests, treatments, and the possibility of empirically "over treating" patients which exponentially increases the cost of care. Because length of stay was significantly higher among efficient hospitals, one strategy to consider is alternative placement of difficult to wean patients to an intermediate care floor and coordinate rehabilitative services with physical and occupational therapies to work on improving the respiratory function of patients who fail to wean. Without knowing the specifics of how treatment differs between efficient and inefficient hospitals, these are only cost-reducing suggestions.

Various suggestions are provided for further study, and cost-reduction strategies associated with mechanical ventilation have been presented. Mechanical ventilation is extremely high resource-consuming and additional studies are needed to establish standards of care associated with quality and cost-effectiveness.

Limitations

There are several limitations of this study. The characteristics of ancillary support in the different UHC hospitals are not known. For purposes of this study, it was assumed that the various ancillary services identified as inputs did offer similar services. However, the significance in respiratory services among inefficient hospitals may suggest that different types of services were provided by inefficient hospitals as compared to efficient hospitals. In addition, the quality provided by the services is not known and may account for the significant differences in both length of stay and respiratory services.

Also, a limitation to this study may be the reporting of charges instead of cost. Cost information is generally confidential between competing hospitals; therefore, the authors wished to maintain the confidentiality of the UHC hospitals cost of resources. However, cost reporting would have been more beneficial to individual hospitals in determining excessive resource consumption and identifying strategies to decrease immoderate use of resources.

There are limitations of using a large databank such at the UHC data for secondary analysis. Hospitals may have variations in their reporting and accuracy of the data may be questioned. However, the contracting firm which oversees data collection for the UHC comment about the scrupulous effort and rigor in retrieving data for UHC. Because this study was a secondary analysis, the four hospitals were deleted due to missing data because the authors were unable to retroactively search for the missing data.

Another limitation involves the results of DEA. To consider the quality of output, the authors made adjustments to the output variables to make them appropriate for the DEA model. Because of these adjustments, three hospitals which had no patients transferred or expired were automatically taken out of the model. Therefore, the DEA model may underestimate the number of efficient hospitals.

Other limitations include the identification of only four ancillary charge inputs. It would be helpful to know the utilization of other ancillary services. Additionally, no information about professional hours per patient is reported. These limitations exert the need for continued technical efficiency analysis of mechanical ventilation services.

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