ASSESSING THE ECONOMIC & CLINICAL VALUE OF NON-INVASIVE POSITIVE PRESSURE VENTILATION

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ABSTRACT:

New medical technology is attributed as bearing a large responsibility for our ongoing rise in health care costs. They are one of the most nagging reasons for hospital expenses being driven up and profit margins dwindling away. The cost of health care, however, serves as motivation for healthcare executives to demand medical technology that not only enhances quality of care, but also lowers the costs of managing each patient's health condition. Healthcare executives have an opportunity to identify and extract substantial economic gains from new medical interventions and emerging technology. This article presents a case study in the use of evidenced-based management control of healthcare delivery costs relative to the adoption of new technology. It provides a model for hospital executive decisions to adopt and manage the costs, economic returns and quality of care implications relative to new medical technology. Noninvasive Positive Pressure Ventilation (NPPV) for Acute Respiratory Failure (ARF) is used as the case study example.

Process. We conducted a retrospective analysis of 215 patients presenting with dyspnea at South Miami Hospital during the period January 2004 through December 2004. Our study objective was to identify the clinical outcomes and cost efficacy resulting from the implementation of a patient management protocol encompassing treatment of qualifying patients with NPPV in lieu of endotracheal intubation and mechanical ventilation. South Miami Pulmonary Services under the project direction of Maureen Lintner, RRT, Senior Therapist, collected aggregate patient data pertaining to patient indications, the number of patients successfully treated with NPPV and those with mechanical ventilation per indication, admissions to general hospital and ICU following initial treatment, average lengths of stay per patient indication and admission, costs of care and reimbursement. Data output from South Miami's hospital information system was transferred to a Respironics "NPPV Technology Usage Effectiveness and Economic Impact Analysis" model (Microsoft Excel® based) for evaluation of findings.

Findings. Of the 215 patients, 134 were successfully ventilated with NPPV (a 62.3% aggregate success rate). NPPV success rates per indication resulted in an expected wide range depending upon case severity. Patients successfully treated with NPPV were referred to general hospital admission while the remaining 81 mechanically ventilated patients were admitted to intensive care (ICU). Total inpatient days for the NPPV group was 1,782 resulting in an ALOS of 13.3 days. The 81 mechanically ventilated patients compiled 2,127 days for an ALOS of 26.3 days. Information on complications and in-hospital mortality was not collected. Total cost for the 134 patients treated with NPPV was $4,053,004, an average of $30,246 per patient. For the 81 patients mechanically ventilated and admitted to ICU, the total cost of care was $5,964,809, an average of $73,640 per patient. From a Pro-Forma perspective the savings from the protocol encompassing the "routing" of qualifying patients to NPPV from mechanical ventilation and endotracheal intubation resulted in a savings of $5,814,756 for the year.

Acute Respiratory Failure:

Use of NPPV Versus Mechanical Ventilation

Acute respiratory failure (ARF) is a respiratory dysfunction resulting in abnormalities of oxygenation or ventilation (the elimination of CO_2) severe enough to threaten the function of vital organs. It may occur in a variety of pulmonary and non-pulmonary disorders. Symptoms of ARF comprise a combination of the underlying disease and hypoexemia or hypercapnia. The prevalent symptom is dyspnea. Because ARF symptoms and signs are neither specific nor sensitive, clinicians are obliged to obtain arterial blood gas analysis and maintain a "high level of wariness" when it is suspected.

The treatment of patients with ARF encompasses (1) therapy directed at the underlying disease, (2) respiratory support to maintain adequate gas exchange, and (3) general supportive care.[1]

Ventilatory support comprises airway patency maintenance and clinical confirmation that the alveolar is adequately ventilated. Treatment options for this are noninvasive positive pressure ventilation (NPPV), endotracheal intubation, and mechanical ventilation. Mechanical ventilation possesses potential complications, which have lead to the rise in popularity of NPPV.

Potential complications of mechanical ventilation include nosocomial pneumonia, lung atelectasis and overdistension, and barotrauma. Atelectasis and overdistension results when the tip of the endotracheal tube migrates into a main bronchus. Barotrauma may occur in patients whose lungs are overdistended by excessive tidal volumes, often when airflow obstruction causes hyperinflation.[2] Other potential complications are acute respiratory alkalosis caused by overventilation and hypotension resulting from elevated intrathoracic pressure.

NPPV has extensive published evidence in support of therapy for COPD, hypoexemic respiratory failure, and early extubation of mechanically ventilated patients.[3] Likewise, Chesnutt et al. report NPPV as first line of therapy for COPD patients with hypercapnic respiratory failure who can protect and maintain airway patency. Studies have shown the efficacy of NPPV in reducing intubation rates, general hospital and ICU stays, lowering in-hospital mortality, nosocomial pneumonia, other complications, improving arterial blood gas (ABG) data, and enhancing prospects for patient survival.[4]

Is NPPV Cost Effective?

Several studies have reported on the impact that NPPV has on cost containment. Brochard et al., for example, in a study of five centers in Europe, compared the therapy outcomes of 85 patients suffering from acute exacerbation of COPD.[5] Forty-three (43) patients within the study cohort were treated with NPPV and the remaining 42 (control group) via mechanical ventilation. Mean hospital length of stay for the NPPV group was 23 days (range +/- 17 days) relative to 35 days (range +/- 33 days) for the control group. Comparative in-hospital mortality was 4 (9%) and 12 (29%) respectively. Girou, et al. reported measurable differentiation in adverse events within a matched case control study of NPPV versus mechanical ventilation in COPD.[6] The study cohort numbered 50 per patient segment wherein 18% of the NPPV group sustained nosocomial infection relative to 60% in the mechanical ventilated group. Similar findings were reported for nosocomial pneumonia (8% versus 22% respectively). Mean days of mechanical ventilation were 6 in the NPPV group compared with 10 for the mechanical ventilation group. Days in ICU were 7 and 15 respectively and mortality rates were reported at 4% and 26%. Lightowler et al. conducted a meta-analysis relative to the use of NPPV for COPD exacerbation whereby findings in eight studies reviewed included a significant lowering of treatment failure risk, a reduction in the risk of mortality, the risk of endotracheal intubation, treatment complications, and hospital stay.[7] Moreover, the overall impact of NPPV in fifteen randomized controlled trials pertaining to acute exacerbation of COPD included the prevention of intubation, decreases in the number of days of mechanical ventilation, lowered mean lengths of hospital and ICU stay, decreases in mean cost of care, and lowered in-hospital mortality.[8]

In a study of 43 mechanically ventilated patients, 25 with COPD, who had failed spontaneous breathing trials for three consecutive days, Ferrer et al. reported comparisons of two groups randomized as extubation and NPPV versus continued intubation and repeated spontaneous breathing trials.[9] The NPPV group had shorter invasive ventilation (9.5 +/- 8.3 v. 20.1 +/- 13.1 days), shorter ICU stay (14.1 +/- 9.2 v. 25.0 +/- 12.5 days), lowered hospital stay (27.8 +/- 14.6 v. 40.8 +/- 21.4 days), less need for endotracheal intubation (5% v. 595), lower incidence of nosocomial pneumonia (24% v. 59%) and septic shock (10% v. 41%), and better ICU survival (90% v. 59%).

Nava et al. reported relative findings in a COPD study of NPPV weaning from 48 hours of mechanical ventilation wherein groups were randomized within pressure support ventilation (PSV) and NPPV. Relative duration of mechanical ventilation was 16.8 +/- 11.8 days for PSV versus 10.2 +/- 6.8 days for NPPV. Comparable time in ICU (24.0 +/- 13.7 for PSV and 15.1 +/- 5.4 for NPPV), survival (72% PSV and 92% NPPV), and nosocomial pneumonia occurrence (7 PSV and 0 NPPV) were significant.

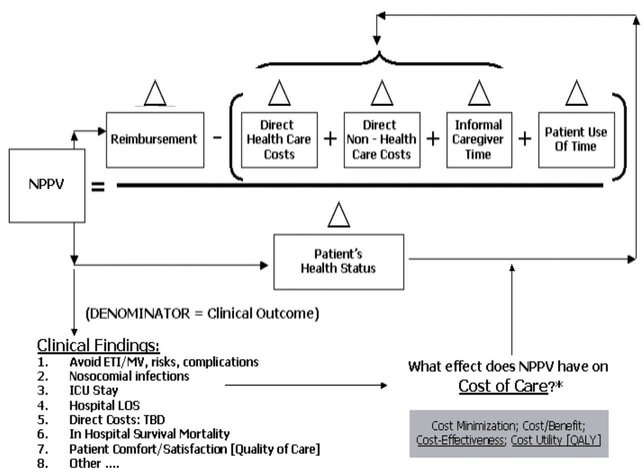
These findings are indicative of success for use of NPPV versus mechanical ventilation as a standard of care in the management of COPD acute exacerbation. Likewise, Kacmarek reports its viability for cardiogenic pulmonary edema when hypercarbia is present, its usefulness for weaning in some patients, and its effectiveness in some patients with hypoxemic ARF.[10]

NPPV Economics

To learn the prospective economic value of NPPV first hand, we began our evaluation by establishing a *Technology Economic Impact* template (displayed in Figure 1) for assessing new diagnostic and therapeutic technology. This formula presents the economic value derived from a new technology relative to its clinical benefits. It enables a hospital executive to analyze the use of a new diagnostic test, device or therapy, which require the consumption of both direct healthcare resources (such as medical supplies and a pathologist's or clinician's time) and non-healthcare resources (such as transportation). The new technology may also require the use of caregiver time and time expended by the patient for treatment. The Δ symbol denotes that we are interested in determining the relative changes in resource consumption resulting from the intervention, compared with the resources consumed for existing or alternative processes.

The reimbursement received by the hospital is a reflection of the payer mix of net revenue secured in relation to costs of utilized resources. The numerator then portrays the change in net cash flow or operating income depending upon financial vehicles used to acquire the technology. For the purposes of this case study, derivation of the hospital's mean cost of care relative to its reimbursement mix pertains to reimbursement minus direct hospital costs only.

FIGURE 1: Is NPPV Cost Effective?



The denominator – the patient's health status – represents the change in clinical outcome based upon the technology's use relative to results from current or alternative clinical processes. While the avoidance of fractures is the primary patient objective, there may be a blend of objectives, including reductions in morbidity, mortality, length-of-stay, unnecessary referrals, hospital admissions and readmissions.

Another health status metric may be a patient's quality-adjusted life years (QALY) remaining after the new technology intervention. The clinical outcome, in turn, affects subsequent healthcare costs. The arrows indicate this relationship.

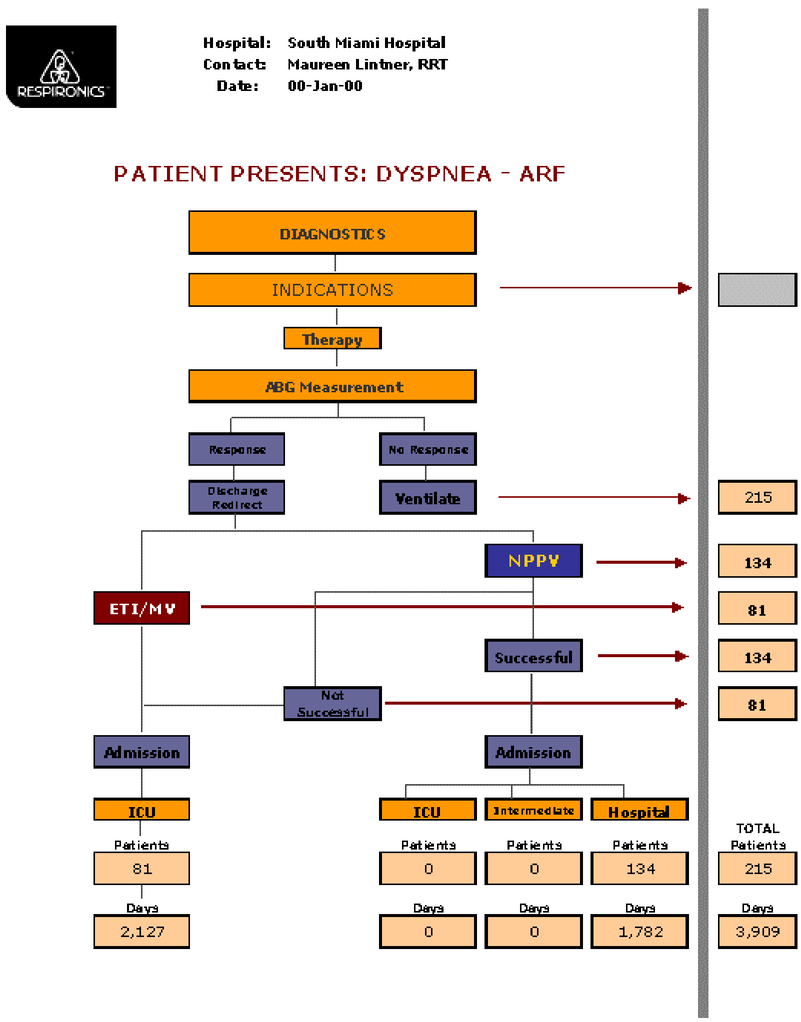
We applied this *Technology Economic Impact* model to a retrospective *NPPV Usage Effectiveness* study of patients presenting during January 2004 through December 2004 with several indications during at South Miami Hospital, in Miami, Florida.

NPPV At South Miami Hospital

South Miami's Pulmonary Services received 215 patients presenting with dyspnea during the twelve-month period of January 2004 through December 2004. With the intent of decreasing costs and length of stay while improving clinical outcomes, the department had established a protocol several years earlier for patients with impending ARF. NPPV was offered to patients who were deemed viable candidates and were unresponsive to initial medical therapy. A Respironics BiPAP Vision® ventilatory support system with monitor was used for a thirty-minute trial wherein upon patient stabilization, an arterial blood gas (ABG) measurement was taken to evaluate adequacy of ventilation.

Of the 215 patients, 134 were successfully ventilated with NPPV (a 62.3% success rate).[11] These patients were the referred to general hospital admission while the remaining 81 patients mechanically ventilated were transferred to intensive care (ICU). Figure 2 displays South Miami's patient care protocol.

Figure 2: South Miami Patient ARF Protocol



South Miami's ARF patients were classified in accordance to a designated APR-DRG indication (3M, Minneapolis, Minnesota). Figure 3 shows patient segmentation per indication and ventilation process (NPPV and mechanical).

NPPV Success Rates

An examination of NPPV success rates per indication resulted in an expected wide range depending upon case severity.

Figure 3: ARF Patients per Indication

South Miami Hospital
Pulmonary Services
January 2004 – December 2004

PATIENT INDICATIONS (Mechanical Ventilation & NPPV)

APR-DRG	Indication	Vent	NPPV	Total
4	Trach w/DMV	17	5	22
121	Other Respiratory	6	3	9
130	Respiratory Severe	17	8	25
133	Pulmonary Edema	6	20	26
136	Respiratory Moderate	2	6	8
137	Major Respiratory	3	7	10
139	Other Pneumonia	7	19	26
140	COPD	2	19	21
190	Acute Mycardial Infarction	7	8	15
194	Heart Failure	11	38	49
862	Other After Cam	0	0	0
950	Extensive Procedure	3	1	4
	TOTAL	81	134	215

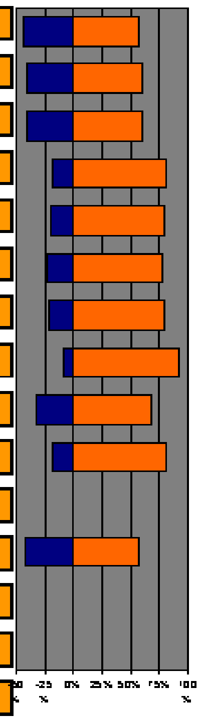
Figure 4 shows findings of low success for four indications. All involved high severity and extensive therapy (Tracheal Tube w/ Mechanical Ventilation: 22.7%, Other Respiratory: 33.3%, Respiratory Severe: 32.0%, and Extensive Procedure: 25.0%).

Acute Myocardial Infarction cases produced a moderate NPPV success rate of 53.3% while the remaining indications were within a 70% - 90% success rate range.

Figure 4: NPPV Successes Per Indication

NPPV SUCCESSES

Indication	NPPV	Total	Success Rate	Success (%)
Trach w/DMV	5	22	22.7%	
Other Respiratory	3	9	33.3%	
Respiratory Severe	8	25	32.0%	
Pulmonary Edema	20	26	76.9%	
Respiratory Moderate	6	8	75.0%	
Major Respiratory	7	10	70.0%	
Other Pneumonia	19	26	73.1%	
COPD	19	21	90.5%	
Acute Mycardial Infarction	8	15	53.3%	
Heart Failure	38	49	77.6%	
Other After Cam	0	0	NA	
Extensive Procedure	1	4	25.0%	
TOTAL	134	215	62.3%	



Hospital Length of Stay

Mean length of stay in the hospital for NPPV patients was 13.3 days versus 26.3 days for patients mechanically ventilated and admitted to ICU. This was not surprising given case severity indications. Four indications (Tracheal Tube w/ Mechanical Ventilation, Respiratory Severe, Major Respiratory, and Extensive Procedure) as expected resulted in above average lengths of stay regardless of NPPV success and admission to either hospital or ICU. Figure 5 displays ALOS in the hospital and ICU per indication.

Figure 5: Length of Stay Per Indication

ADMISSIONS	NPPV Successful				Not Successful		
Indication	Admit	Hospital	Days	ALOS	Admit ICU	Days	ALOS
No NPPV Trial Attempted							
Trach w/DMV	5	5	383	76.6	17	973	57.2
Other Respiratory	3	3	35	11.7	6	128	21.3
Respiratory Severe	8	8	212	26.5	17	517	30.4
Pulmonary Edema	20	20	174	8.7	6	78	13.0
Respiratory Moderate	6	6	28	4.7	2	27	13.5
Major Respiratory	7	7	131	18.7	3	53	17.7
Other Pneumonia	19	19	217	11.4	7	56	8.0
COPD	19	19	164	8.6	2	26	13.0
Acute Mycardial Infarction	8	8	81	10.1	7	46	6.6
Heart Failure	38	38	334	8.8	11	150	13.6
Other After Cam	0	0	0	NA	0	0	NA
Extensive Procedure	1	1	23	23.0	3	73	24.3
TOTAL	134	134	1,782	13.3	81	2,127	26.3

NPPV Cost Effectiveness

Mean cost of care per admission the NPPV Success group and mechanical ventilation patients admitted to ICU varied substantially. Total cost for the 134 patients treated with NPPV was $4,053,004, an average of $30,246 per patient. For the 81 patients mechanically ventilated and admitted to ICU, the total cost of care was $5,964,809, an average of $73,640 per patient. Average cost of care is in direct relation to the case severity of the patients presenting with dyspnea. Patient care management protocol influenced type of therapy, however, resulting in an expected positive correlation between clinical outcome and cost of care. Figure 6 displays South Miami's financial summary per patient groups reflecting healthcare resource consumption.

Figure 6: NPPV & MV Financials Summary

Date: 10/01/05
Hospital: South Miami Hospital
Contact: Maureen Lintner, RRT
Period: Period Covered: JAN '04 - DEC '04

NPPV Effectiveness Project Financial Summary

	NPPV	ETI/MV	TOTAL	Variance
Patients	134	81	215	
Admissions	134	81	215	
Revenue/Reimbursement			$0	$0
Patient Management Costs	$4,053,004	$5,964,809	$10,017,813	$1,911,805
FMV NPPV Equipment Lease Costs	0		0	
EBITDA	NA	NA	NA	NA
Depreciation & Amortization	0		0	
Net Interest Expenses	0		0	
Net Income Before Taxes	NA	NA	NA	NA
Capital Expenditures	0		0	
CASH FLOW CONTRIBUTION	NA	NA	NA	NA

RESOURCE CONSUMPTION	NPPV	Ventilate
Admissions - Hospital	134	
Admissions - Intermediate Care		
Admissions - ICU		81
Inpatient Days - Hospital	1,782	
Inpatient Days - Intermediate Care		
Inpatient Days - ICU		2,127

Patient Management Costs	NPPV	Ventilate
Aggregate	$4,053,004	$5,964,809
Hospital	$0	
Intermediate Care	$0	
ICU	$0	$0
Complications	$0	$0
TOTAL COSTS	$4,053,004	$5,964,809
Mean Cost Per Admission	$30,246	$73,640

Conclusion

The NPPV initiative implemented by South Miami was successful in terms of producing significant improvements in clinical outcomes and lowering the cost of care for patients presenting with dyspnea and a suspicion of ARF. Figure 7 displays a "Fast Facts" overview of results.

Figure 7: Executive Summary of Results

FAST FACTS

Date:	Report Date: October 15, 2005
Hospital:	South Miami Hospital
Contact:	Maureen Lintner, RRT
Period:	Period Covered: JAN '04 - DEC '04

	NPPV		Ventilated	TOTAL	Bench Mark
Patients	215	Trial Attempted	81	215	
NPPV Successes	134				
Success Rate	62.3%				

	Hospital	Inter Care	ICU	ICU	TOTAL	Bench Mark
Admissions	134			81	215	
Inpatient Days	1,782			2,127	3,909	
Mean LOS	13.3	NA	NA	26.3	18.2	
Nosocomial Pneumonia	0	0	0	0	0	
Pneumonia Rate	0.0%	NA	NA	0.0%	0.0%	
Other Complications	0	0	0	0	0	
Complications Rate	0.0%	NA	NA	0.0%	0.0%	
In-Hospital Mortality	0	0	0	0	0	
Mortality Rate	0.0%	NA	NA	0.0%	0.0%	
Total Revenue ($000)	$0			$0	$0	
Mean Revenue per Patient	$0			$0	$0	
Total Cost of Care ($000)	$4,053			$5,965	$10,018	
Mean Cost per Patient	$30,246			$73,640	$46,594	
Cash Flow Impact ($000)	NA			NA	NA	

Of a total 215 patients managed for dyspnea, 134 were successfully treated (an NPPV Success Rate of 62.3%) with NPPV and admitted to general hospital care. Patients not treated with NPPV were, as expected, those with severe illnesses (indications of tracheal tubing with mechanical ventilation, severe respiratory illness, require extensive procedures, and other respiratory indications labeled as severe cases. We did not capture data on complications occurring within each group of patients, but anticipate that the substantially higher mean cost of care per MV, ICU patient ($73,640 for the mechanical ventilation, admitted to ICU group; $30,246 for the NPPV, general hospital admission group) reflects, in part, adverse events. Mortality rate data were also not collected for this study.

Average length of stay per NPPV patient was 13.3 days versus 26.3 per patient mechanically ventilated and admitted to ICU. The variance in ALOS had a strong impact on healthcare resources consumed and total cost of care.

From a Pro-Forma perspective the savings from the protocol encompassing the "routing" of qualifying patients to NPPV from mechanical ventilation and endotracheal intubation resulted in a savings of $5,814,756 for the year (reflecting 215 patients at the mean cost of MV care at $73,640 reduced by the savings from of 134 patients treated with NPPV at the lower mean cost of $30,246). This, however, does not take into account the varying severity of each case and prospective ensuing adverse events. See Chart 1 for a Pro Forma results summary.

Chart 1: Pro-Forma NPPV Cost

Patient Population	**215**
Mean Cost of Care (ET/MV)	**$73,640**
Pro-Forma Total Cost	**$15,832,600**
Patients (NPPV Successful)	**134**
Mean Cost of Care (NPPV)	**$30,246**
NPPV Total Cost	**$4,053,004**
Pro Forma Cost (@ $73,640 per Patient)	**$9.867,760**
Savings From NPPV	**$5,814,756**

The derived savings are based upon an assumption of 134 patients treated with endotracheal tubing and mechanical ventilation at a mean cost of $70,640 versus an NPPV mean cost of $30,246.

Finally, with regard to Net Cash Flow contribution of clinically and cost effective strategies such as NPPV, CFOs are cautioned to pay attention to reimbursement as well as costs they look to the economic value added to their hospitals. Reimbursement received per coded DRG is currently based upon healthcare resources deployed and consumed (measured in terms of Relative Value Units). Accordingly, patient care management strategies that utilized more resources may generate higher reimbursement than programs that improve clinical outcomes and contain costs.

This appears to be the case with NPPV at South Miami Hospital where average reimbursement per NPPV is $29,416 versus $78,574 for mechanical ventilation. The reimbursement may be a reflection of formulae that compensates for resources consumed adjusted for patient case severity or possibly a coding issue.

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Endnotes

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[1] Good general overviews of Acute Respiratory Failure include Mark S. Chesnutt, MD and Thomas J. Prendergast, MD, "Lung" (sub sections: "Acute Respiratory Failure" and "Acute Respiratory Distress Syndrome", in Lawrence M. Tierney, Jr. et al. (Editors), *Current Medical Diagnosis and Treatment* (CMDT 2003: Pages 306 – 311), Lange Medical Books/McGraw Hill and Marc Moss, MD and Roland H. Ingram, Jr., MD, "Acute Respiratory Distress Syndrome", Eugene Braunwald, MD, et al. (Editors), *Harrison's 15th Edition: Principles of Internal Medicine* (2001, McGraw Hill), Pages 1523 - 1531

[2] Ibid., Chesnutt, et al.

[3] See Dean R. Hess, PhD, RRT, FAARC, "The Evidence for Noninvasive Positive Pressure Ventilation in the Care of Patients in Acute respiratory Failure: A Systematic Review of The Literature", *Respiratory Care*, (Volume 49, Number 7; July 2004), Pages 810 - 829

[4] Hess, ibid. and Janet M. Poponick, MD et al., "Use of a Ventilatory Support System (BiPAP) for Acute Respiratory Failure in the Emergency Department", *Chest: Clinical Investigations in Critical Care* (Volume 116, Number 1; July 1999), Pages 166 – 171. Also, earlier testimony includes Abou-Shala N., Meduri, G.U., "Noninvasive Mechanical Ventilation in Patients With Acute Respiratory Failure", *Critical Care Medicine* (1996: Volume 24), Pages 705 – 715; Hillberg, r.E., Johnson, D.C., "Noninvasive Ventilation", *New England Journal of Medicine* (1997: Volume 337), Pages 1746 – 1752; and Jasmer, R.M., et al., "noninvasive Positive Pressure For Acute Respiratory Failure: underutilized or Overrated?", *Chest* (1997: Volume 111) pages 1672 – 1688

[5] Brochard, et al. "Acute Exacerbation COPD", *New England Journal of Medicine* (1995: Volume 333), Page 817

[6] Girou, et al., "Matched case Control Study of NPPV Versus Mechanical Ventilation", *JAMA*, (2000: Volume 284) Page 2361

[7] Lightowler, J. V., et al., "Non-Invasive Positive Pressure Ventilation to Treat Respiratory Failure Resulting From Exacerbation of Chronic Obstructive Pulmonary Disease: Cochrane Systematic Review and Meta-Analysis, *BMJ,* (2003: Volume 326, Number 7382), Pages 185 - 189

[8] Kacmarek, Robert M. PhD, RRT, "Noninvasive Positive Pressure Ventilation: State of The Art!" *Respironics Annual Conference Presentation* (2005: Carlsbad, CA)

[9] Ferrer, M. et al., "Noninvasive Ventilation During Persistent weaning failure: a randomized Controlled Trial", *American Journal of Respiratory Critical Care Medicine* (2003: Volume 168, Number 1), Pages 70 - 76

[10] Kacmarek, op cite

[11] For a discussion of a similar thirty-minute trial protocol, see the Janet M. Poponick, M.D. et al. study to identify patient characteristics early in the course of acute illness to predict NPPV success: "use of a Ventilatory Support System (BiPAP) for Acute respiratory Failure in the Emergency Department" *Chest: Clinical Investigations in Critical Care* (Volume 116, Number 1; July 1999), Pages 166 – 171