Original Article

Cost-effectiveness of noninvasive ventilation for chronic obstructive pulmonary disease-related respiratory failure in Indian hospitals without ICU facilities

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ABSTRACT

Introduction: The majority of Indian hospitals do not provide intensive care unit (ICU) care or ward-based noninvasive positive pressure ventilation (NIV). Because no mechanical ventilation or NIV is available in these hospitals, the majority of patients suffering from respiratory failure die. **Objective:** To perform a cost-effective analysis of two strategies (ward-based NIV with concurrent standard treatment vs standard treatment alone) in chronic obstructive pulmonary disease (COPD) respiratory failure patients treated in Indian hospitals without ICU care. **Materials and Methods:** A decision-analytical model was created to compare the cost-effectiveness for the two strategies. Estimates from the literature were used for parameters in the model. Future costs were discounted at 3%. All costs were reported in USD (2012). One-way, two-way, and probabilistic sensitivity analysis were performed. The time horizon was lifetime and perspective was societal. **Results:** The NIV strategy resulted in 17.7% more survival and was slightly more costly (increased cost of $101 (USD 2012) but resulted in increased quality-adjusted life-years (QALYs) (1.67 QALY). The cost-effectiveness (2012 USD)/QALY in the standard and NIV groups was $78/QALY ($535.02/6.82) and $75/QALY ($636.33/8.49), respectively. Incremental cost-effectiveness ratio (ICER) was only $61 USD/QALY. This was substantially lower than the gross domestic product (GDP) per capita for India (1489 USD), suggesting the NIV strategy was very cost effective. Using a 5% discount rate resulted in only minimally different results. Probabilistic analysis suggests that NIV strategy was preferred 100% of the time when willingness to pay was >$250 2012 USD. **Conclusion:** Ward-based NIV treatment is cost-effective in India, and may increase survival of patients with COPD respiratory failure when ICU is not available.

KEY WORDS: Chronic obstructive pulmonary disease, cost-effectiveness of ward-based NIV, no access to intensive care unit care, noninvasive positive pressure ventilation, respiratory failure, USD/quality-adjusted life-year

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INTRODUCTION

A cost-effective analysis is important in all public health decision-making, and critical in low- and middle-income countries where health care resources are severely limited and rationing decisions are necessary.[1-6] Although some of the hospitals in these low-income countries have intensive care capabilities, many more do not have these advanced capabilities.[7] In hospitals without intensive care units (ICUs), survival of patients with respiratory failure is dismal as no rescue mechanical ventilation is possible. The only option available for these moribund patients is transfer to a hospital with an ICU, if one is even available.

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Because of financial constraints, it may be important for low-income countries to consider less traditional mechanisms to treat respiratory failure patients. Mechanical ventilation is expensive, with cost-effectiveness estimates of 29,000–110,000 $/QALY, (1994 USD).[8,9] This is likely not a reasonable cost expenditure for many low-income countries. However, these studies estimating cost effectiveness were performed in developed countries where the cost may be substantially inflated compared to the cost of critical care and mechanical ventilation in low-income countries.[10,11]

Newer treatments for respiratory failure include noninvasive positive pressure ventilation (NIV) initially followed by mechanical ventilation for NIV failures.[12-15] This approach has been shown to reduce the need for endotracheal intubation, and is associated with lower mortality, less complications, and reduced length of stay in conditions such as chronic obstructive pulmonary disease (COPD).[12-15] Additionally, several studies have documented NIV as cost-effective.[16] As noninvasive ventilation can occur safely outside the ICU, this modality may be a potential option in hospitals without ICU facilities.[17-19] In this approach, although rescue mechanical ventilation for noninvasive ventilation failures would not be available, it may still offer a survival advantage at a reasonable cost for many patients.

The purpose of this study is to compare the cost-effectiveness of the use of ward-based NIV plus standard treatment to standard treatment alone in COPD-related respiratory failure patients in India.

MATERIALS AND METHODS

This study was submitted to the Investigational Review Board of St. John Hospital and Medical Center and was determined to be exempt from review.

Following recommendations from the US Public Health Service Panel on Cost-effectiveness in Health and Medicine and the American Thoracic Society (ATS) workgroup, the analysis was conducted from the societal perspective, with a lifetime time horizon and the assumption of a discount rate of 3% for costs and health effects.[20,21] Additionally, a second analysis was performed using a 5% discount rate.[20] The Indian Consumer Price Index (CPI) was used to inflate historical cost estimates to 2012. All currency is reported in US dollars (2012).

Model and estimates

The model used in the analysis was a decision tree with one-way sensitivity analysis, two-way sensitivity analysis, and probabilistic (Monte Carlo) analysis. Estimates for variables in the model were drawn from the literature. Figure 1 reveals the decision tree utilized in the analysis.

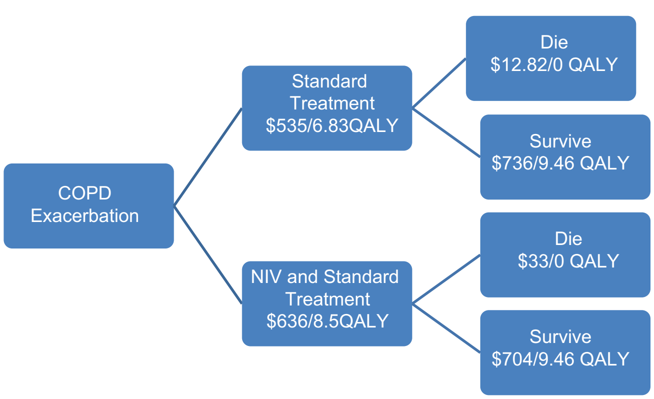

Figure 1: Decision tree

Table 1 reveals the estimates used in the model, and the sources.

Mortality estimates

As it was assumed that mechanical ventilation was not available, mortality estimates in both groups (NIV and standard treatment) were estimated from the proportion of individuals requiring rescue mechanical intubation in the studies comparing NIV (with standard care) and standard care alone patients. Several authors have performed meta-analysis of NIV and standard treatment in COPD respiratory failure patients, and reported the rescue intubation rate.[12-14,22] Although the estimates were all similar, as we needed to choose one, we used the intubation rate from the most recent meta-analysis, which also had the largest number of patients and included all the studies from the previous meta-analysis.[13] For sensitivity analysis, we used means and standard deviations (SDs). The mean and SD were also used in the probabilistic analysis, with a beta distribution.

Total length of stay (LOS) estimates

All studies comparing NIV with the standard treatment found that the NIV group had a shorter total LOS. Data from Indian references were preferred as local practices are likely to be representative of true Indian LOS. Only two Indian randomized trials of COPD getting NIV or standard treatment were found. Prasad (2007, randomized, N = 19, LOS standard treatment = 13.33± 4.69 days and NIV treatment = 9.63± 1.41 days) and Khilnani (2010, randomized, N = 40, LOS standard treatment = 17.8± 2.6 days and NIV treatment, LOS = 9.4± 4.3 days) were both reviewed.[30,31] No data were provided on LOS for standard or NIV treatment groups in patients not needing rescue intubation, and both Indian studies had >50% intubation rate (which increases LOS). One older study (Brochard, 1995, randomized, N = 85, France based) noted total LOS for Standard treatment not needing intubation of 20 (±6) days and NIV treatment not requiring intubation of 17 (± 9) days (difference of 3 days).[32]

Estimates from both the Indian studies were very close regarding the total LOS of the NIV treatment group (9.4 vs 9.6 days), and the study that showed the smallest difference in LOS between the two groups (the Prasad study with a difference was 3.7 days compared to the Khilnani study with a difference of 8.4 days) was utilized to prevent any bias in the study against NIV treatment.[30,31] This was additionally supported by the older non-Indian study, which noted a difference in LOS of 3 days, and the large recent meta-analysis, which found that the difference in LOS for all the 11 studies included was 2.68 days.[13,36]

For sensitivity analysis, a range of ± 50% LOS was chosen. In probabilistic analysis, the means and SDs were used with a normal distribution. Regarding the LOS from all studies conducted so far, comparison of NIV to standard treatment has revealed that the NIV treatment group

Table 1: Estimates and sources used in the model

Variable	Point estimate	Notes, assumptions, sources
Probability of death in NIV* treatment	0.101 (50/496) 95% CI**=0.0771-0.1306 (modified Wald method)	References reviewed: McCurdy, Ram. Keenan, Agarwal, and Lightowler.[12-14,22,23] Estimates used came from McCurdy as the meta-analysis was more recent (2012) and included the largest sample size (496).[13] Mortality rate was estimated as the intubation rate in the NIV treatment arm. The mean and confidence intervals used in sensitivity analysis and beta distribution were used in probabilistic analysis
Probability of death in standard treatment	0.278 (140/504) 95% CI=0.2404-0.3185 (modified Wald method)	References reviewed: Plant, McCurdy, and Ram, Keenan, and Lightowler.[12-14,17,22] Estimates used came from McCurdy as this meta-analysis was most recent (2012) and included the largest sample (504).[13] Mortality rate was estimated as intubation rate in the standard treatment arm. The mean and confidence interval used in sensitivity analysis with beta distribution was used in Monte Carlo analysis
Cost ward hospitalization in standard treatment group, and cost ward treatment after NIV in NIV group	12.82 USD/day	References reviewed include: Tabish (costs per all hospitalizations, not COPD specific), Dror (costs per all hospitalization, not COPD***-specific), Cooke (US-based cost analysis), Shah (costs assumed were equal to hospital revenue), Plant (UK-based cost analysis), Murthy (only had total hospitalization costs, not per day), and Veettil.[8,17,24-28] We choose to use Veettil data for estimates as data from 2012, India-specific, COPD-specific, available per day, and based on prospective micro-cost analysis technique. Data were obtained from a government hospital.[28] For sensitivity analysis, the cost of hospitalization varied ±50% used, and for probabilistic analysis, triangular distribution with ±50% was used
QALY**** NIV and standard treatment in survivors after discharge	QALY=11.7 Years lived=15	Linko study of utilities of patients after respiratory failure was a source of QALY and life expectancy (after treatment with only NIV).[29] It was assumed that QALY was not different for survivors of either standard or NIV care after discharge. For sensitivity analysis and for Monte Carlo analysis, ±50% QALY used. For years, in sensitivity analysis, 0-25 years were used, and for probabilistic analysis 0-25 years were used with a triangular distribution
Total days hospitalized (LOS=length of stay) in standard and NIV treated survivors	Standard treatment: 13.33±4.69 days NIV treatment 9.63±1.41 days	Data from Indian references were preferred as local practices are likely to be representative of true Indian LOS. Two Indian randomized trials of COPD getting NIV or standard treatment were reviewed Prasad R (2007, randomized, *N*=19, LOS standard treatment=13.33±4.69 days and NIV Treatment=9.63+/-1.41 days) and Khilnani (2010, randomized, *N*=40, LOS standard treatment=17.8+/-2.6 days and NIV treatment LOS=9.4±4.3 days). No recent data were available on LOS for standard treatment or NIV treatment in those not intubated, and both studies had >50% intubated (which increases ave LOS).[30,31] One older study (Brochard, randomized, *N*=85, 1995) noted that total LOS for standard treatment did not need intubation of 20 (±6) days and NIV treatment did not require intubation of 17 (±9) days.[32] The difference between the two groups was 3 days, providing additional support for using the Prasad estimates (difference in his study was 3.7 days). In sensitivity analysis, a range of +/= 50% was chosen. In probabilistic analysis, the means and standard deviations were used with a normal distribution. The LOS from all studies ever conducted, comparing NIV to standard treatment have found that the NIV treatment group always had a lower LOS. Because of a larger standard deviation in standard treatment LOS, it may be possible in probabilistic analysis for values chosen in LOS standard treatment to be less than the values selected for LOS NIV treatment. As this is not realistic, the "if" function was used in probabilistic analysis such that if the LOS in the standard treatment group was less than LOS in the NIV group, the LOS of the NIV treatment group would be equivalent to the LOS of the standard treatment group
Days receiving NIV	4	Only one study was found that provided data on the number of days of NIV in COPD respiratory failure patients (who did not need rescue intubation (Brochard, 1995)).[32] In this study, patients were on NIV for a mean of 4 days (SD=4). As this was the only estimate available, it was the one used. This was a reasonable assumption as the number of days in previous studies (that did not separate out those patients needing rescue intubation) was 3-4 days. For sensitivity analysis, 0–6 days was used. For probabilistic analysis, the mean and standard deviations were used [4(4) days]. To prevent a negative value chosen for days of NIV, the MAX function was utilized such that if a negative value was selected in probabilistic analysis, a zero (i.e., less than 1 day) would be utilized
Days of standard treatment before death Days of NIV before death	12	Data from Indian references were preferred as local practices are likely to be representative of true LOS. Indian studies (Khilnani, Prasad) were reviewed.[30,31] The number of days till death was assumed to be the number of days before mechanical ventilation. Although not specifically reported, both studies noted either rapid improvement with treatment (both the standard group and NIV treatment group) or rapid decline so that by 24 h the majority of the patients needing intubation were intubated. Khilnani noted rapid deterioration in standard treatment patients needing intubation but less rapid deterioration in NIV patients. In this analysis, 1 day was chosen for standard treatment and 2 days for NIV treatment. In sensitivity analysis, a range of 0-3 days for standard treatment and a range of 0-4 days for NIV was used.[31]
Willingness to pay	4,467 USD	WHO-CHOICE† initiative for cost-effectiveness recommends=3x GDP per capita as considered cost-effective. The Indian World Bank, 2012 estimate of 1489 (USD) and multiplied times 3[33-35]

Contd...

Table 1: Contd...

Variable	Point estimate	Notes, assumptions, sources
Cost NIV days	16.66 USD	Only study estimating "ward-based" cost of NIV was by Plant (study conducted in Europe).[17] The cost of hospitalization was 30% higher for NIV ward days compared to standard treatment ward days; so, we estimated that the cost of NIV ward days was 30% more than standard ward daily costs. For probabilistic sensitivity analysis, ±50% used.
Annual cost/year/patient with chronic COPD	43.69	The Indian study (Murthy) of chronic costs for moderate to severe COPD (1320 R in 2001) and Indian CPI‡ calculator was used to convert to 2012 rupee (INR).[27,34] Currency converter used to convert from Indian National Rupee to USD.[35] For probabilistic sensitivity analysis, ±50% used

*NIV: Noninvasive positive pressure ventilation, **CI: Confidence interval, ***COPD: Chronic obstructive pulmonary disease, ****QALY: Quality-adjusted life-year, STD: Standard, †WHO-CHOICE: World Health Organization-Choosing Interventions that are Cost-Effective, ‡CPI: Consumer price index

always had a lower LOS. Because of larger SD in standard treatment LOS, it may be possible in an iteration of the probabilistic analysis for the value chosen in LOS standard treatment to be less than the value selected for LOS NIV treatment. As this is not realistic, the "if" function was used in the probabilistic analysis such that if the value chosen for LOS in the standard treatment group was less than value chosen for LOS in the NIV group, then the value for LOS in the NIV group used in that iteration of the probabilistic analysis would be the LOS of the standard treatment group (making the LOS equivalent in both groups for that iteration of the probabilistic analysis).

Days on NIV

Only one study was found that provided data on the number of days of NIV in COPD respiratory failure patients (that did not need rescue intubation).[32] In this study, patients were on NIV for a mean of 4 days (SD = 4). For sensitivity analysis, 0–6 days was used. For probabilistic analysis, mean and SDs were used.

Days before the death of paitents in the NIV and standard treated groups

Data from Indian references were preferred as local practices are likely to be representative of the actual number of days before death. As described earlier, only two Indian randomized trials of COPD getting NIV or standard treatment were found.[30,31] The number of days till death was assumed to be the number of days before mechanical ventilation. Although not specifically reported, both studies noted either rapid improvement with treatment (both standard and NIV treatment groups) or rapid decline so that by 24 h, the majority needing intubation had been intubated. One study also noted a more rapid deterioration in the standard treatment patients needing intubation and less rapid deterioration in NIV patients.[31] Other studies were also reviewed but no specific data were provided on days before intubation.[12,13,15,22,31,36,37] In this analysis, 1 day (range of 0–3) was chosen for the standard treatment group and 2 days (range 0–4) was chosen for the NIV treatment group. To test the impact of this assumption, two-way sensitivity was performed.

Cost estimates

The cost of health care in India, even hospital-based health care, is much less expensive than in the US and other developed countries.[38] There were numerous cost estimates available for hospitalization cost.[24-28] We chose to use the most recent cost analysis.[28] In Indian studies, all NIVs were performed in the ICU. The cost for noninvasive ventilation in the wards was not available for Indian hospitals. There was a cost comparison study for ward noninvasive ventilation versus ward standard treatment that was performed in England.[17] In this English study, the noninvasive ventilation group in the wards had 30% higher costs than standard care in the wards. As this was our best estimate, for this study, we added 30% to the Indian cost of standard treatment in the wards to estimate the cost for noninvasive ventilation in the wards in India. In all of the cost sensitivities and probabilistic analyses, we assumed the cost could vary ±50%.

To determine the chronic costs for moderate to severe COPD, an Indian study was used (1320 Rupees in 2001) and the Indian Consumer Price Indicator (CPI) calculator was used to inflate to 2012 rupees (INR).[27,34] Currency converter used to convert from INR to USD.[35] For sensitivity and probabilistic analysis, ±50% was used. The TreeAge "annuity" function was used to discount into the future the yearly costs of COPD treatment and QALY's with a 3% discount rate, with a second analysis done at 5% discount rate.

Discount rate and willingness to pay

As recommended by the reference case, a discount rate of 3% was used, with a second analysis at 5%.[20] Willingness to pay (WTP) estimate was based on 3x gross domestic product (GDP) per capita, as suggested by the World Health Organization (WHO).[4]

QALY estimates

We made the assumption that the QALY's were equivalent in standard and NIV treatment groups after discharge. This assumption is supported by a study evaluating standard and non-invasive ventilation for COPD patients in India that found no difference at 4–6 weeks in blood gas parameters and pulmonary function variables.[30] It is also intuitive that once discharged alive, there is no difference between the two groups as there is no evidence showing that using NIV or not using NIV causes any long-term negative consequences. QALY estimates came from a study that measured QALY and survival years in 105 COPD respiratory failure patients treated only with

NIV or standard therapy.[29] As the cost of treatment for COPD was discounted in the future (using the annuity function in TreeAge), the QALY was also discounted in the future. For sensitivity analysis and probabilistic analysis, ±25% was used.

Statistical analysis

Cost-effectiveness analysis, one-way sensitivity [incremental cost effectiveness ratio (ICER)], and two-way sensitivity analysis (mortality rates, days till death, and LOS in both strategies) were performed. Monte Carlo (probabilistic) sensitivity was performed with 50,000 iterations.

Analyses were conducted using software (TreeAge Pro 2014; Williamstown, MA, USA). All costs WERE inflated using Indian Consumer Price Index and discounted in the future using 3% discount rate. A secondary analysis was also performed assuming a future 5% discount rate.

RESULTS

The mortality rate in these strategies (i.e. the rescue intubation rate from the largest meta-analysis) was 0.101 for the NIV group and 0.278 for the standard treatment group. Table 2 reveals the ICER. The cost (USD 2012)/QALY for the standard treatment and the NIV treatment were $78/QALY ($535.02/6.82) and $75/QALY ($636.33/8.49), respectively, and did not change much in the probabilistic analysis [Table 3]. The NIV group was slightly more expensive (by approximately 100 USD) but resulted in increased effectiveness (QALY increased by 1.67 QALY). ICER was only $61 USD/QALY. This was substantially lower than the GDP per capita for India (1489 USD), suggesting the NIV strategy was very cost-effective.[33] Using a 5% discount rate resulted in only minimally different results.

Results of the one-way sensitivity analysis on ICER are revealed in Figure 2. This tornado diagram reveals one-way sensitivity of all of the relevant variables. It represents how the expected value for the ICER would vary as each variable was processed through its range of possibilities (while all other variables were held constant). Notably, ICER remains very low and is always positive (implying that through the range of values for each variable, the NIV strategy is always cost-effective). Figure 3 reveals the results of the cost-effectiveness analysis displaying the increased cost but also increased effectiveness in the NIV strategy.

A two-way sensitivity analysis varying the probability of death in both groups at the same time (while holding all other variables constant) is shown in Figure 4. Notably, the range of the NIV strategy was preferred throughout the entire range of the standard treatment probabilities. However, to determine what death probabilities would cause the standard treatment strategy to be preferred, the ranges for possible death were made equivalent. When this was done, it was clear that the strategy preferred was always the NIV strategy until the death rate in the

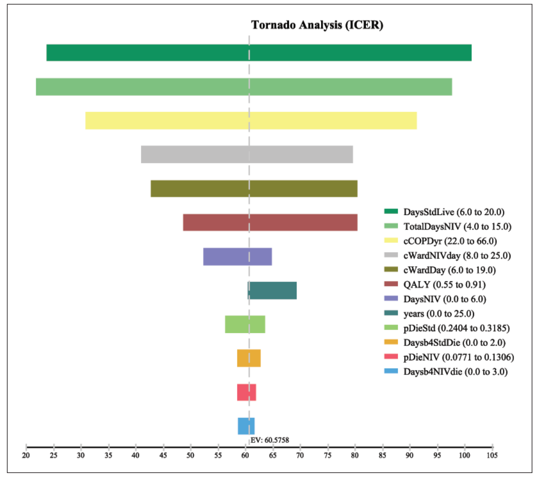

Figure 2: Results of one-way sensitivity analysis on incremental cost-effectiveness ratio. (ICER) for all variables. QALY = QALY after hospitalization, DStdLive = Days of standard treatment in survivors, cDayWrd = Cost of day on ward, cDayNivWrd = Cost of NIV treatment on ward per day, cCOPDyr = Cost of health care for COPD per year, TotaDayNIV = Total LOS in days of NIV treatment in survivors, DaysStdDie = Days of standard treatment before death, DaysNIVDie = Days of NIV treatment before death, pDieNIV = Probability of death in the NIV group

Table 3: Results of the probabalistic analysis (50,000 iterations)

	Standard treatment	Noninvasive ventilation treatment	Incremental
Cost			
Mean	534.66	637.07	102.41
Standard deviation	101.82	109.72	
Effectiveness			
Mean	6.83	8.50	1.67
Standard deviation	0.78	0.89	
ICER: (50,000 output distribution) iterations			
Mean	60.47 (95% CI=±0.39)		
Standard deviation	44.46		

Table 2: ICER report WTP*=4467

Strategy	Discount (%)	Cost	Incremental cost	Effectiveness (QALY**)	Incremental Eff	Cost/Effectiveness	ICER***
Standard treatment	3	535.06		6.82		78	
NIV treatment	3	636.33	101.27	8.49	1.67	75	61
Standard treatment	5	485.91		6.0		81	
NIV Treatment	5	575.12	89.21	7.47	1.47	77	61

*WTP: Willingness to pay, **QALY: Quality-adjusted life-year, ***ICER: Incremental cost-effectiveness ratio

NIV group was equal to the death rate in the standard treatment [Figure 4]. As all studies conducted to date have found a decreased intubation rate (which is the marker for death in this model that assumes no ICU facilities available so that those needing intubation would die) in the NIV group, this again supports the NIV treatment. Additionally, this is intuitive as the cost of NIV treatment is more than the cost of standard treatment; hence, when the mortality rates become equal, it would be the point that would make the standard treatment more cost-effective (same probability of death but less expensive).

Two-way sensitivity analysis evaluating the impact of varying the days hospitalized in the two groups found that the NIV strategy was preferred through the entire range, even when the total days hospitalized for NIV was more than for standard treatment. Two-way sensitivity analysis on the number of days before death in both the groups also found the NIV strategy to be the preferred strategy through the ranges.

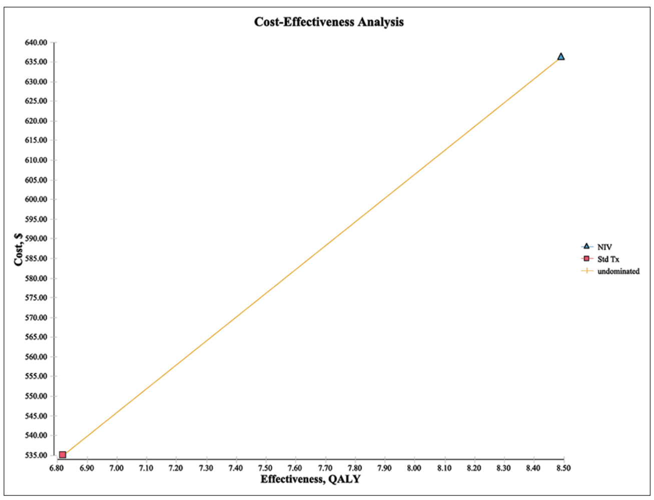

Figure 3: Cost-effectiveness analysis with 3% discount rate

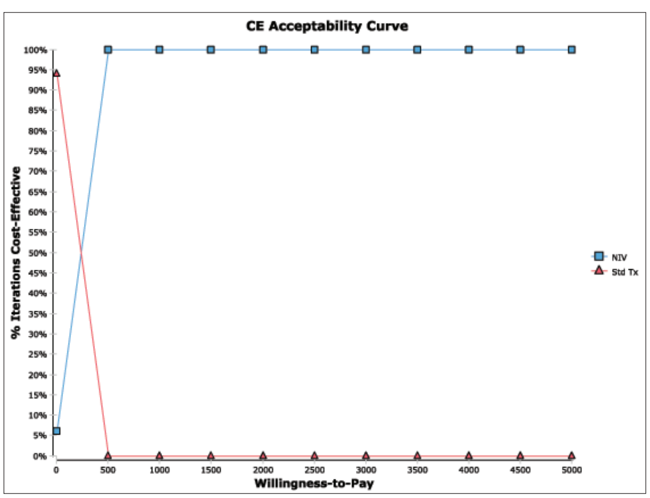

Figure 5: Cost-effectiveness acceptability curve. CE = Cost-effectiveness

Figure 5 reveals the results of the cost-effectiveness acceptability curve. Figure 6 reveals the incremental cost-effectiveness results from the probabilistic analysis (the ellipse is the 95% confidence interval). NIV was the preferred strategy and in some of the iterations, was not only cost-effective (results located below 0 cost where the NIV strategy was less costly) but more effective as well.

DISCUSSION

This cost-effectiveness analysis pertains to the specific population of COPD patients suffering from respiratory failure who were hypothetically treated in an Indian hospital without access to any ICU facilities. Using mortality information alone (when mortality is assumed to occur at the point of rescue intubation in published data), the noninvasive ventilation strategy would save lives

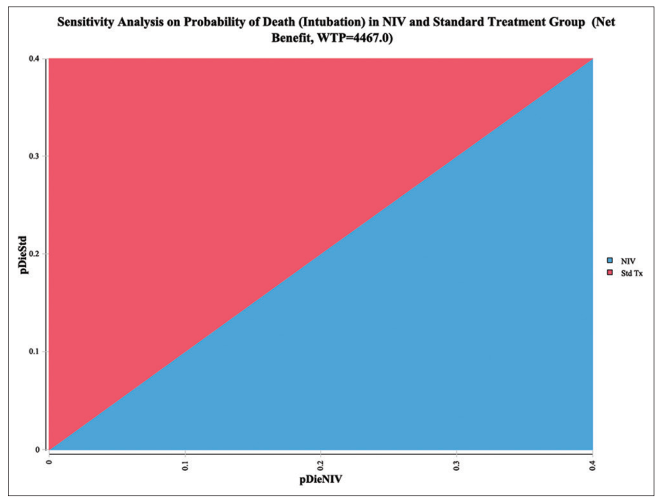

Figure 4: Two-way sensitivity analysis for probability of death in the NIV group and the standard treatment group.pDieNIV = Probability of death in NIV group, pDieStd = Probability of death in standard treatment group, WTP = Willingness to pay

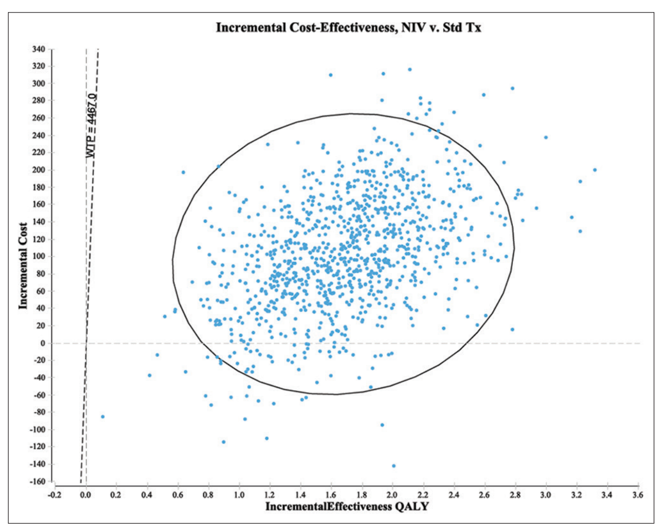

Figure 6: Incremental cost-effectiveness

and would be cost-effective. The noninvasive ventilation strategy was slightly more costly in comparison to standard treatment but had improved effectiveness (more QALYs). According to the WHO Choosing Interventions that are Cost-Effective (CHOICE) initiative, interventions are considered very cost-effective if the cost-effectiveness per year is less than the GDP per capita, which for India is approximately 1,489 (USD 2012).[33] The NIV strategy had cost-effectiveness of only 61 (USD 2012)/ QALY (636.33/8.49), which is only 4% of the Indian GDP/ capita. Although it may not be appropriate to extrapolate the cost-effectiveness of NIV to every low-income country, the fact that the cost estimate/QALY was so low suggests that there may be additional opportunities for noninvasive ventilation in other low-income countries when mechanical ventilation is not available.

In India, there is still a critical shortage of ICU beds; there is an estimated need of 5 million ICU beds annually but only 70,000 are available.[39] One-analysis of Indian ICUs found that medical professionals in small hospitals managed 40% of the inpatient beds with limited facilities.[25] The potential for noninvasive ventilation to improve health care in India may be significant.

This analysis focused on a specific population—COPD patients with respiratory failure. Some studies reveal lower mortality, less complications (pneumonia, sepsis, etc.), and lower LOS in NIV treated patients. Some other conditions [acute respiratory distress syndrome (ARDS), acute respiratory infections] may or may not benefit from noninvasive ventilation.[23,37,40-42] One recent study estimated the cost for hospitalization for acute respiratory infections was substantial at $54.00–355.00 (USD).[43] The addition of NIV for respiratory failure in these patients may positively impact this expenditure. However, additional evaluations are necessary before the cost-effectiveness of noninvasive ventilation can be extrapolated in other conditions.

Several studies that were used for estimates provided NIV in the ICU setting. This cost analysis assumed that care would be provided in the ward, as several studies (including one India-based study) have suggested this is safe and effective.[8,30] Ward-based noninvasive ventilation is becoming more accepted in India, which makes this strategy more realistic.[8,30]

Economic consequences of this strategy that contribute to increased cost in the NIV group include less mortality and therefore, more cost after hospitalization in the higher proportion of survivors. However, even with increased survival, the incremental cost-effectiveness was only $61 (2012 USD).

One limitation in this study is that the cost-effectiveness analysis is based on estimates drawn from the literature. Several estimates had large variances associated with them. As suggested by the ICER tornado diagram [Figure 3], several parameters where estimations were based on assumptions (days of NIV before death, days of standard treatment before death, and days of NIV) were not critical to the cost analysis. Additionally, even with the large variance, the ICER never crossed 0 in the tornado diagram.

In order to address some of the limitations arising out of using literature-based parameters, Indian-based estimates were used when available. Additionally, estimates varied widely in the probabilistic analysis and the noninvasive ventilation strategy was still preferred. While the best estimates for cost-effectiveness analysis would ideally come from a large randomized controlled trial from different hospitals in India, this analysis may provide the rationale for perusing that type of analysis.

CONCLUSION

Cost effectiveness analysis may prove a powerful tool in addressing the difficulty of traditional ICU health care in low- and middle-income countries. This analysis establishes preliminary evidence for the cost-effectiveness of ward-based NIV treatment for COPD-induced respiratory failure in hospitals without ICUs in India. In this analysis, we found that noninvasive ventilation treatment was cost-effective at 61 (USD, 2012)/QALYs, substantially less than 1 xGDP/QALY, which in India is 1489 (USD, 2012). As 40% of the hospitals in India have no ICU, ward-based noninvasive ventilation may become a crucial new option to provide some life-saving respiratory support. Future research needs to assess the cost-effectiveness of noninvasive treatment in other low- and middle-income countries, as the potential benefits may be substantial.

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