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Linda L. Chlan
Mayo Clinic

Annie Heiderscheit
Augsburg University, heidersc@augsburg.edu

Debra J. Skaar
University of Minnesota - Twin Cities

Marjorie V. Neidecker
The Ohio State University

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Linda L. Chlan, PhD, RN, FAAN
Mayo Clinic
Rochester, MN

Annie Heiderscheit, PhD, MT-BC, LMFT
Augsburg College
Minneapolis, MN

Debra J. Skaar, PharmD, FCCM
University of Minnesota
Minneapolis, MN 55455

Marjorie V. Neidecker, PhD, MEng, RN, CCRP
The Ohio State University
Columbus, OH 43212

Institutions where work was performed:
Mayo Clinic, Rochester, MN
The Ohio State University, Columbus, OH
Augsburg College, Minneapolis, MN
University of Minnesota, Minneapolis, MN

Corresponding Author:
Linda L. Chlan, PhD, RN, FAAN
Mayo Clinic
200 First St. SW
Rochester, MN 55905
Phone: 507-255-7859
Email: chlan.linda@mayo.edu

Address for reprints:
Linda L. Chlan, PhD, RN, FAAN
Mayo Clinic
200 First St. SW
Rochester, MN 55905
Reprints will not be ordered

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Mechanical ventilation; costs; cost-effectiveness analysis; sedation; intensive care unit, music listening

Abstract

Objective: Non-pharmacological interventions like music listening have been shown to reduce anxiety and sedative exposure among critically ill mechanically ventilated patients. Whether music intervention reduces ICU costs is not known. The aim of this study was to examine ICU costs for patients receiving a patient-directed music intervention (PDM) compared with patients who received usual ICU care.

Design: A cost-effectiveness analysis using decision analytic modeling from the hospital perspective was conducted to determine if a PDM intervention was cost-effective in improving patient-reported anxiety. Cost savings were also evaluated. One-way and probabilistic sensitivity analyses determined the influence of input variation on the cost-effectiveness.

Setting: Midwestern intensive care units.

Patients: Adult patients from a parent clinical trial receiving ventilatory support in the ICU.

Interventions: Patients receiving the PDM intervention were provided with a MP3 player, noise-abating headphones, and music tailored to individual preferences by a music therapist. The PDM intervention was compared to usual care.

Measurements and Main Results: The base case cost-effectiveness analysis estimated PDM reduced anxiety by 19 points on the Visual Analogue Scale for Anxiety (VAS-A) with a reduction in cost of $2,322 per patient compared with usual care, resulting in PDM dominance. The probabilistic cost-effectiveness analysis found average PDM costs were $2,155 less than usual care and projected that cost saving is achieved in 70% of 1,000 iterations. Based on break-even analyses, cost saving is achieved if the per-patient cost of the PDM intervention remains below $2,651, a value 8 times the base case of $329.

Conclusions: PDM is a cost-effective intervention for reducing anxiety in mechanically ventilated ICU patients.

INTRODUCTION

Care in the intensive care unit (ICU) is costly for patients who require mechanical ventilation (MV). From 2000-2010, cost per ICU day increased 61.1% from $2,669 to $4,300 (1). It is estimated that approximately $80 billion is spent on critical illness annually in the U.S. (2). Today there is a concerted effort to manage pain, agitation and delirium per clinical practice guidelines (3) that recommend light levels of sedation for MV patients to promote weaning as soon as indicated. However, these guidelines do not adequately address the significant symptom of anxiety commonly experienced by these patients (4, 5). Interventions that ameliorate anxiety, without adverse side effects and are cost-effective, would be a welcome addition to the care for ventilated ICU patients. One such non-pharmacological intervention is music listening. Patient self-initiated music listening while receiving MV has been shown to reduce anxiety and sedative exposure (6). However, whether or not music intervention reduces ICU costs is not known. The aim of this study was to examine ICU costs in patients enrolled in a parent clinical trial testing patient-directed music intervention compared with those who were randomized to usual ICU care.

METHODS

Study Design

The objective of this secondary data analysis study was to perform a cost-effectiveness analysis of the experimental patient-directed music (PDM) intervention compared to usual care (UC) in MV adults during their ICU stay. A break-even cost analysis of the PDM intervention was also conducted. Using a simple decision analysis model, we compared the ICU costs of patients who received the experimental PDM intervention to patients who received UC.

We followed guidelines for conducting a cost-effectiveness analysis with a few notable exceptions (7). Because the payment structure between hospitals and payers encourages providers to minimize costs, the analysis was from the healthcare provider's perspective rather than the societal perspective (8). The time horizon for the analysis was limited to the patient's ICU stay. Although a longer time window is typically used in cost-effectiveness studies, there are no known long-term health effects for the PDM intervention at this time and patients enrolled in the parent study were not followed after their ICU stay (7).

Patient Population

The target population was adult ICU patients receiving MV for acute respiratory failure. The primary data source was a randomized clinical trial testing the efficacy of a PDM intervention (n=122) or UC (n=122) on anxiety and sedative exposure in mechanically ventilated ICU patients (6). Details from the clinical trial are available elsewhere (6).

The base-case patient in this analysis (Supplemental Table 1) was modeled on the parent study clinical trial results (6). The mean (*SD*) patient age was 59.2 (14.4) years and the ICU admission illness severity score was 63.2 (21.6) based on the APACHE (Acute Physiology, Age, Chronic Health Evaluation) III. Upon enrollment, patients had been in the ICU 10.7 (9.8) days and receiving MV for 8.9 (9.4) days. The adjusted (illness severity and pre-study ICU days) mean (*SE*) ventilator days for patients randomized to the PDM intervention was 4.9 (0.58). The adjusted mean (*SE*) ventilator days for patients randomized to UC was 6.3 (0.57). Patients exited the study when they were extubated, withdrew, transferred from the ICU, or died (6).

Clinical Effects Used in Cost-Effectiveness Evaluation

Anxiety scores. The primary clinical outcome measure for this analysis was patients' self-reported anxiety scores. Although preference-weighted quality-of-life scores are widely accepted as the ideal effectiveness measure in economic evaluations, quality-of-life measures were not collected in the parent study; we used anxiety scores as a proxy clinical end point. Anxiety ratings were obtained daily from all study patients using a 100-mm Visual Analogue

Scale for Anxiety (VAS-A) (6). The VAS-A was presented vertically like a thermometer; subjects indicated their current level of anxiety from 0 (not anxious at all) to 100mm (most anxious ever) in response to the question "how are you feeling today". Anxiety level is determined by the distance in mm from zero to the level indicated. Because the average patient was enrolled in the intervention 5.7 days, the average anxiety score for each group on study day 5 was included as the base-case effectiveness value in the cost-effectiveness analysis. Average anxiety scores were varied ±25% in the sensitivity analysis.

ICU length of stay and total days of ventilator support*.* The mean (*SD*) total length of ICU stay for PDM and UC patients was 19.4 (13.7) days and was not statistically significant between groups. The mean (*SD*) total ventilator days during ICU stay was 14.4 (1.05) for UC patients and 12.3 (1.06) for PDM patients. Because the PDM group received MV for a greater number of days prior to enrollment in the clinical trial, the mean total ventilator days for the PDM group was conservatively estimated to be 13.0, after adjustment for APACHE III illness severity score and pre-study ICU days (6). Average ICU days and total days intubated were varied ±25% in the sensitivity analysis.

Sedative Drug Dosages*.* Mean drug dosages of nine commonly administered intravenous (IV) sedative and analgesic medications were included in the analysis: dexmedetomidine, diazepam, fentanyl, haloperidol, hydromorphone, lorazepam, midazolam, morphine, and propofol (6). Mean sedative drug dosages were varied ±25% in the sensitivity analysis.

Costs Components

Only direct medical costs, expressed in 2015 U.S.$, were included in this analysis (Supplemental Table 1). Total ICU cost was calculated for each study group by including the following component costs: ICU stay, MV, sedative and analgesic medications, and PDM intervention. Drug costs and physician costs were collected in 2015 U.S.$, and hospitalization costs were adjusted to 2015 U.S.$ using the Medical Care component of the Consumer Price

Index (9). Clinical effects were measured over a time period less than one year and, therefore, did not require discounting.

***Patient-Directed Music Intervention Cost**.* Patients randomized to the PDM group were provided with a MP3 player, noise-abating headphones, and music tailored to individual preferences by a board-certified music therapist (MT-BC). The estimated cost of one PDM intervention set of MP3 player and headphones was $70, but because the equipment was sterilized and reused, the mean cost per patient was only $4.14. The estimated mean hourly rate of a MT-BC was $65.00 based on national data (10). The MT-BC spent an average of five hours with each PDM patient. The total mean cost of the PDM listening was $329.14. In the sensitivity analysis, the MT-BC's hourly rate and time spent with the patient varied from 0% to +100%, and the cost of the equipment was varied from $4.14 to $70 to provide a conservative estimate of the intervention.

ICU and mechanical ventilation cost. The daily cost of ICU stay and the incremental cost of MV were obtained from claims data of 51,000 patients from approximately 300 general medical/surgical hospitals in the U.S. (11). The mean daily cost of ICU care for mechanically ventilated patients and non-mechanically ventilated patients have been converted from 2002 U.S.$ to 2015 U.S.$; costs were varied ±50% in the sensitivity analysis.

Sedative Drug Cost. To obtain mean IV sedative and analgesic drug costs per patient in each group, the drug dosages were multiplied by the lowest published unit price of the average wholesale price (12). The dosage unit selected for sedative cost calculations was the concentration and vial size used by the hospital pharmacy for preparing the medication for administration in the ICU. The lowest listed unit price was selected to most closely reflect the average cost paid by the hospital to acquire the drug, which typically includes significant discounts and rebates (13). Because ICU medication costs are included in the hospitalization cost, the difference in PDM versus usual care sedative drug costs was deducted from the total cost for the PDM group. We assumed the difference in the average cost of all non-sedative drugs administered to the patients in each group was equivalent and, therefore, was not included in this analysis. In the sensitivity analysis, the average wholesale price was considered the maximum cost, and the lower endpoint of the range was -25% of this value.

Physician Cost. Because the cost of the primary treating physician is typically not included in the ICU charges, the physician cost was estimated using current procedural terminology codes and Medicare fee schedules (14). The cost was varied ±50% in the sensitivity analysis.

Sensitivity Analysis

To address uncertainly in the true values of the model variables, a one-way sensitivity analysis was performed for all variables in the model over their plausible ranges (Supplemental Table 1). Threshold analyses were performed to determine the value of key variables for which one alternative, PDM or UC, becomes less costly than the other. Threshold values were calculated for the reduction of days of MV with PDM, the ICU cost with MV for day three and later, and the cost of the PDM intervention. A probabilistic sensitivity analysis using Monte Carlo simulation was also performed to allow varying all variables simultaneously. Normal distributions were used for anxiety scores and gamma distributions for sedative dosages, length of care variables, ICU costs, and physician costs to model the outcomes obtained from the parent study. Uniform distributions were used for sedative and PDM intervention costs to allow a more conservative evaluation of the impact of these variables on the cost-effectiveness results. Average values of 1,000 simulations were calculated and displayed on an incremental cost versus incremental effectiveness scatter plot. The percent of iterations in the simulation resulting in PDM as cost-effective over UC was determined for various values a health system would be willing to pay to reduce a patient's anxiety level by one VAS-A unit.

We used TreeAge Pro 2017 (TreeAge Software, Inc.; Williamstown, MA) and Stata 12 (Stata; College Station, TX) for analyses. Approval for this project was received by the Mayo Clinic Institutional Review Board.

RESULTS

Base-Case Analysis

Under base-case conditions, the mean anxiety scores were 33 for PDM and 52 for UC; total ICU costs were $131,379 for PDM and $133,701 for UC (Table 1). Thus, in the base-case analysis, the experimental PDM intervention clearly dominated UC given that PDM provided higher effectiveness at a lower cost.

To calculate cost savings and the break-even cost of the PDM intervention, the average cost and the average cost savings per patient of the PDM intervention was compared to UC. The cost of the PDM intervention, including costs for MT-BC time and equipment, averaged $329 per patient. The cost savings of PDM over UC during the ICU stay included $2,460 in ICU costs, $170 in physician costs, and $22 in sedative medication costs, totaling $2,652, a value 8 times the costs. Therefore, in the base case scenario and independent of patient anxiety scores, these costs and savings correspond to a net savings of $2,322, and PDM is cost-effective when the cost to implement the intervention does not exceed $2,652.

Sensitivity Analyses

One-way sensitivity analyses showed four key variables impacted the dominance of the experimental PDM intervention over UC, that is at some point in the range of values specified for each of these variables, the PDM intervention was no longer both less expensive and more effective than UC assuming the willingness-to-pay for the anxiety score reduction was $0. These variables are: (1) number of days of MV for UC, (2) number of days of MV for PDM, (3) daily ICU cost with MV for ICU day 3 and later, and (4) daily ICU cost without MV (Figure 1). Other cost categories, including PDM intervention costs, physician costs, and sedative medications costs, had a smaller impact on the total cost and did not impact PDM dominance.

A threshold analysis showed how varying the value of the ICU days and daily cost within the sensitivity analysis ranges influenced which alternative produced the lower average total cost per patients. When either the days of MV for UC was less than 13.2 or the days of MV for PDM was greater than 14.2, UC became lower in total ICU costs than PDM. Similarly, when either the daily ICU cost for the third and subsequent days of MV was less than $4,864, UC became the lower cost alternative.

PDM remained the lower cost alternative throughout the entire range of values for all other variables in the one-way sensitivity analyses. Notably, the calculated threshold value for the cost of the PDM intervention where PDM no longer remained more cost effective than UC is $2,652, a value 8 times the base case of $329.

Probabilistic Sensitivity Analysis and Willingness-to-pay

In the probabilistic sensitivity analysis of 1,000 simulations (Figure 2), the average total cost of PDM was $132,473 (*SD* $14,511) compared to $134,628 (*SD* $15,420) for UC. The PDM intervention was less costly and more efficacious than UC in 70% of iterations. However, when a value is placed on the willingness-to-pay to reduce a patient's anxiety level, the proportion of iterations in the simulation in which PDM is more cost-effective increases (Table 2). At a value of $50 for one unit of reduction on the VAS-A, 83.5% of iterations resulted in PDM as superior in cost effectiveness. At a willingness-to-pay of $100, 92.0% of iterations showed PDM as more cost effective.

DISCUSSION

Based on this secondary data analysis, the experimental PDM intervention can save about $2,000/patient and concurrently better manage anxiety with less sedative medication than UC. To the best of our knowledge, this is the first report of the economic evaluation of a non-pharmacological intervention's impact on costs associated with ICU patients receiving MV. A recent search of available literature resulted in one publication on the cost-effectiveness of procedural support music therapy in general medical pediatric patients (15). This single center study reported elimination of sedation, reduced procedural times and decreased staffing needed to complete procedures with the provision of MT-BC provided support during a variety of invasive/ non-invasive procedures with an overall net savings of $74.24/patient. While the $2,000/patient savings modeled in our analysis may seem like a modest amount, the savings have immense potential for future implementation of music intervention in the ICU setting considering the U.S. spends more than $80 billion on critical illness per year, or 3% of total healthcare expenditures (2).

The major contributing factor to the $2,000/patient cost-savings is from the estimated 1.4 fewer days of MV for patients randomized to the experimental PDM intervention, adjusting for illness severity and pre-ICU days prior to study enrollment. These results are in concert with clinical practice guidelines that promote liberation of patients earlier from MV by minimizing sedative medications, leading to better patient outcomes (3). A music listening intervention for appropriately selected patients under the auspices of a MT-BC could have a significant impact on ICU costs, if implemented earlier in the ICU stay. Prospective studies are needed that are designed to test music listening earlier in the ICU stay on salient patient outcomes including costs of ICU care. Methods for appropriate delivery and integration of music listening into ICU practice are also needed.

Findings from the parent study documented patients' self-reported anxiety scores were significantly lower which suggests patients were more comfortable and less anxious in the PDM group than those patients managed with UC. Non-pharmacological strategies are recommended in the ICU PAD guidelines (3) over pharmacological management for prevention and treatment of delirium, a serious complication associated with excessive and prolonged sedative therapy that is estimated to cost the U.S. healthcare system more than $150 billion every year (16). PDM is one non-pharmacological option that should be offered to appropriate ICU patients to help manage anxiety and possibly reduce exposure and risk from excessive sedation without an increase in cost. The influence of music intervention on the incidence of delirium is not known and warrants future investigation.

Although this economic evaluation model of PDM assumed conservative ICU costs, there are several limitations to this study. First, using anxiety scores as an effectiveness metric is nontraditional and lacks the ability for comparison to other interventions measured in standard quality-adjusted life years. However, anxiety is an important symptom to manage in ICU patients and provides a measure of patients´ perceived ICU quality of life. Second, because the effect of PDM on long-term costs and outcomes is unknown, our model focused on ICU stay only. We do believe, though, that PDM may have positive long-term outcomes, and thus this short-term window is conservative. Another limitation related to ICU stay is that in this model, patients who were extubated were assumed to remain extubated for the remainder of their ICU stay, when it's possible some patients may have required re-intubation. Post-ICU benefits of PDM require investigation in future studies. Other limitations include that costs associated with nursing care were not included in this analysis. Patients who can self-manage their anxiety may require less nursing time to deliver sedative medications and should be included in future prospective studies. Likewise, the parent study did not measure ventilator-associated events such as the occurrence of ventilator-associated pneumonia and potential impact on ICU costs. While the parent study focused on the daily measurement of anxiety, we did not measure other symptoms such as pain which may have impacted duration of MV and associated cost-savings. Likewise, the incidence of delirium was not measured in the parent study. Lastly, findings reported here may only be applicable to ICU patients who can participate in a self-administered music intervention.

CONCLUSIONS

Interventions that result in reduced ICU length of stay and/or duration of MV could lead to substantial reductions in total inpatient cost (17). Implementing music listening with preferred selections is one patient-centered intervention that can reduce costs associated with receiving MV and is free of adverse side effects.

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Figure Legends

Figure 1. Tornado diagram showing the one-way sensitivity analysis of the incremental cost-effectiveness ratio for PDM versus UC per unit reduction in VAS-A score.

Model parameters were varied between the ranges shown in parenthesis. Negative values indicate PDM dominated UC throughout the ranges applied in the sensitivity analysis. The vertical bar denotes the base-case incremental-cost effectiveness ratio (ICER).
PDM = patient-directed music, UC = usual ICU care

Figure 2. Scatterplot of probabilistic analyses comparing incremental costs and effects.

This scatterplot depicts the results of 1000 simulations during which the clinical and cost variables were permitted to vary simultaneously; however, the incremental costs and effects are displayed. 70% of iterations fall in in the negative cost range, indicating PDM was the less costly option. The horizontal bar indicates a $0 willingness-to-pay for a unit reduction in VAS-A score.
PDM = patient-directed music, UC = usual ICU care, VAS-A = Visual Analogue Scale for Anxiety