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Economic evaluation of a patient-directed music intervention for ICU patients receiving mechanical ventilatory support

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Abstract

Objective—Music intervention has been shown to reduce anxiety and sedative exposure among 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 (PDMI) compared with patients who received usual ICU care (UC).

Design—A cost-effectiveness analysis from the hospital perspective was conducted to determine if PDMI 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 ICU patients from a parent clinical trial receiving mechanical ventilatory support.

Interventions—Patients receiving the experimental PDMI received a MP3 player, noise-canceling headphones, and music tailored to individual preferences by a music therapist.

Measurements and Main Results—The base case cost-effectiveness analysis (CEA) estimated PDMI reduced anxiety by 19 points on the Visual Analogue Scale-Anxiety with a

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reduction in cost of $2,322/patient compared with UC, resulting in PDM dominance. The probabilistic CEA found average PDMI costs were $2,155 less than UC 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 PDMI remains below $2,651, a value 8 times the base case of $329.

Conclusions—PDMI is cost-effective for reducing anxiety in mechanically ventilated ICU patients.

Keywords

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

INTRODUCTION

Care in the intensive care unit (ICU) is costly, particularly for mechanically ventilated patients (MVPs). 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 MVPs 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 MVPs. One such non-pharmacological intervention is music listening. Patient self-initiated music listening while receiving mechanical ventilation 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 (PDMI).

METHODS

Study Design

The objective of this secondary data analysis study was to perform a cost-effectiveness analysis (CEA) of the experimental PDMI compared to usual care (UC) in adult MVPs during their ICU stay. A break-even cost analysis of the PDMI was also conducted.

We followed guidelines for conducting a CEA 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 CEA, there are no known long term health effects for the PDMI 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 mechanical ventilation for acute respiratory failure. The primary data source was a randomized clinical trial testing the efficacy of PDMI (n=126) or UC (n=125) or noise-canceling headphones (n = 122) on anxiety and sedative exposure in MVPs (6). Parent trial details and Supplemental Data are available elsewhere (6).

The base-case patient in this analysis (Supplemental Table 1) was modeled on the parent study 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 ventilatory support for 8.9 (9.4) days. The adjusted (illness severity and pre-study ICU days) mean (*SE*) ventilator days for patients randomized to the PDMI 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, 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 was mechanically ventilated for a greater number of days prior to enrollment, 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.$, were included in this analysis (Supplemental Table 1). Total ICU cost was calculated for each study group by including the following cost components: ICU stay, mechanical ventilation, sedative and analgesic medications, and PDMI. Drug costs and physician costs were collected in 2015 U.S.$, 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 experimental PDMI were provided with a MP3 player, noise-abating headphones, and music tailored to individual preferences by a board-certified music therapist. The estimated cost of one PDMI 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 music therapist was $65.00 based on national data (10). The music therapist spent an average of five hours with each patient. The total mean cost of the PDMI was $329.14. In the sensitivity analysis, the music therapist's hourly rate and time spent with the patient were 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 mechanical ventilation were obtained from U.S. claims data of 51,000 patients from approximately 300 general medical/surgical hospitals (11). The mean daily cost of ICU care for MVPs and non-MVPs were 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 PDMI versus UC sedative drug costs was deducted from the total cost for the PDMI 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, PDMI or UC, becomes less costly than the other. Threshold values were calculated for the reduction of mechanical ventilation days with PDMI, ICU cost with mechanical ventilation for day three and later, and cost of the PDMI. 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 PDMI 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 PDMI and 52 for UC; total ICU costs were $131,379 for PDMI and $133,701 for UC (Table 1). Thus, in the base-case analysis, the experimental PDMI clearly dominated UC given that PDMI provided higher effectiveness at a lower cost.

To calculate cost savings and the break-even cost of the PDMI, the average cost and the average cost savings per patient of the PDMI was compared to UC. The cost of the PDMI averaged $329 per patient. The cost savings of PDMI over UC 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. PDMI 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 had a large potential effect on the cost per additional unit of VAS-A score reduction and impacted the dominance of the experimental PDMI over UC, when the PDMI 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 ventilated for UC, (2) number of days ventilated for PDMI, (3) daily ICU cost with mechanical ventilation for ICU day 3 and later, and (4) daily

ICU cost without mechanical ventilation (Figure 1). Categories of PDMI costs, physician costs, and sedative medications costs, had a smaller impact on the total cost and did not impact PDMI 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 costs. When either the days of mechanical ventilation for UC was less than 13.2 or greater than 14.2 for PDMI, UC became lower in total ICU costs than PDMI. Similarly, when the daily ICU cost for the third and subsequent days of mechanical ventilation was less than $4,864, UC became the lower cost alternative.

PDMI 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 PDMI where PDMI 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 PDMI was $132,473 (*SD* $14,511) compared to $134,628 (*SD* $15,420) for UC. The PDMI 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 PDMI 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 PDMI as superior in cost effectiveness. At a willingness-to-pay of $100, 92.0% of iterations showed PDMI as more cost effective.

DISCUSSION

Our results demonstrate that the experimental PDMI 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 MVPs' costs. A recent search of available literature resulted in one publication on the cost-effectiveness of procedural 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 music therapist-provided support during invasive/non-invasive procedures with a net savings of $74.24/patient. While the $2,000/patient savings modeled in our analysis may seem modest, 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 mechanical ventilatory support for patients randomized to PDMI. These results are in concert with clinical practice guidelines that promote weaning of MVPs earlier minimizing sedative medications (3). A music listening intervention for appropriately selected patients facilitated by a music therapist could have a significant impact on ICU costs, particularly if implemented earlier in the ICU stay. Prospective studies are needed to test PDMI earlier in the ICU stay inclusive of costs. Methods for 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 PDMI 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 ICU complication that is estimated to annually cost the U.S. healthcare system more than $150 billion (16). PDMI is one non-pharmacological option that should be offered to appropriate ICU patients to help manage anxiety and 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 PDMI assumed conservative ICU costs, there are several limitations to this study. First, using anxiety scores as an effectiveness metric only allows our cost-effectiveness results to be compared to other interventions for reducing anxiety. Comparisons to other interventions measured in standard quality-adjusted life years or more global outcomes such as ICU or hospital survival cannot be made. However, anxiety is a common symptom among MVPs that provides a measure of patients' perceived ICU quality of life. Second, because the effect of PDMI on long-term costs and outcomes is unknown, our model focused on ICU stay only. However, PDMI may have positive long-term benefits, and thus this short-term window is conservative. Another limitation related to ICU stay is that 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 PDMI requires future investigation. 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 associated 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 ICU stay 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 mechanical ventilation could lead to substantial reductions in total inpatient cost (17). Implementing music listening with preferred selections is one patient-centered intervention that can reduce ICU costs and is free of adverse side effects.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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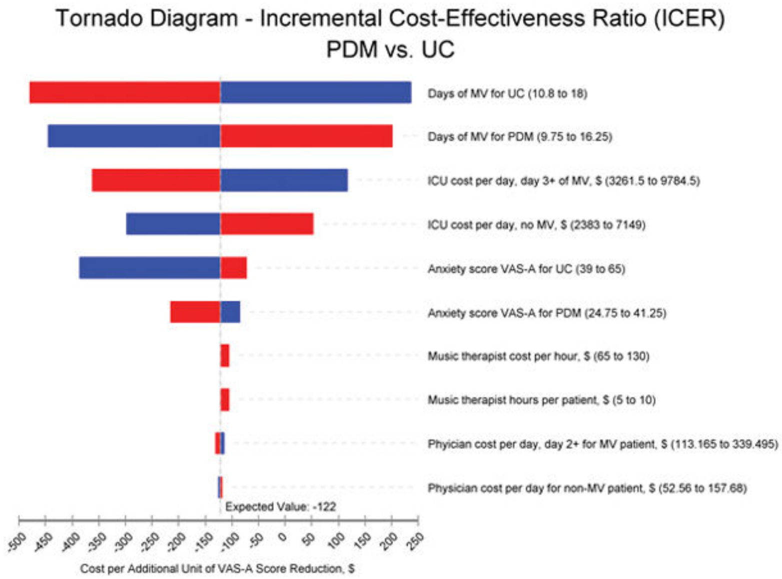

Figure 1.

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 incremental-cost effectiveness ratio (ICER) values indicate PDM dominated UC throughout the ranges applied in the sensitivity analysis. The vertical bar denotes the base-case ICER. The blue portion of the bar represents the ICER range when the parameter is lower than its base case value; the red portion represents the ICER range when the parameter is higher than its base case value.

PDM = patient-directed music, UC = usual ICU care

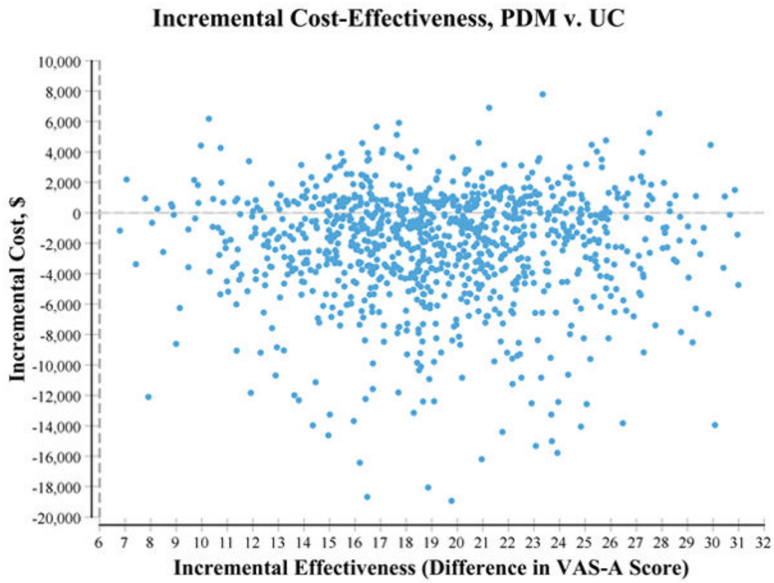

Figure 2.

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

Table 1

Incremental cost-effectiveness ratio of PDM versus UC.

Cost-Effectiveness Components	Patient-Directed Music	Usual Care	Incremental Value
Costs			
Patient-directed music intervention, $	329	not applicable	
ICU cost, $	127,343	129,803	
Physician cost, $	3,728	3,898	
Sedative medication savings during PDM intervention period,[a] $	−22		
Total Cost, $	131,379	133,701	2,322
Effectiveness			
Anxiety Score (VAS-A)	33	52	19
Outcomes			
Incremental cost-effective ratio (ICER),[c] per unit of anxiety score			PDM dominates UC in 70% of iterations

[a]Sedative medications are included in ICU costs and, therefore, no adjustment in sedative medication costs were made for UC.

[b]Benefit-to-cost ratio includes the cost of the PDM intervention and the benefit of reduced ICU, physician, and sedative medication costs.

[c]Incremental cost-effective ratio (ICER) assumes a $0 willingness to pay to reduce the VAS-A score by one unit.

ICU = intensive care unit, PDM = patient-directed music, UC = usual ICU care, VAS-A = 100-mm Visual Analogue Scale for Anxiety.

Table 2

Probability that each alternative is cost-effective for a maximum willingness-to-pay per unit of anxiety score reduction.

Willingness-to-Pay per unit of Anxiety Score Reduction on VAS-A by Group	**Dollar**	**Amount**			
	$0	**$25**	**$50**	**$75**	**$100**
PDM	70.1%	75.8%	83.5%	90.1%	92.0%
UC	29.9%	24.2%	16.5%	9.9%	8.0%

PDM = patient-directed music, UC = usual ICU care, VAS-A = Visual Analogue Scale for Anxiety