Decision Analysis for a Data Collection System of Patient-controlled Analgesia With a Multi-attribute Utility Model

I-Jung Lee[1,2], Shih-Yu Huang[1,2], Mei-Yung Tsou[1,2], Kwok-Hon Chan[1,2], Kuang-Yi Chang[1,2,3]*

[1]*Department of Anesthesiology, Taipei Veterans General Hospital,* [2]*National Yang-Ming University School of Medicine, and* [3]*Division of Biostatistics, College of Public Health, National Taiwan University, Taipei, Taiwan, R.O.C.*

Background: Data collection systems are very important for the practice of patient-controlled analgesia (PCA). This study aimed to evaluate 3 PCA data collection systems and selected the most favorable system with the aid of multi-attribute utility (MAU) theory.

Methods: We developed a questionnaire with 10 items to evaluate the PCA data collection system and 1 item for overall satisfaction based on MAU theory. Three systems were compared in the questionnaire, including a paper record, optic card reader and personal digital assistant (PDA). A pilot study demonstrated a good internal and test–retest reliability of the questionnaire. A weighted utility score combining the relative importance of individual items assigned by each participant and their responses to each question was calculated for each system. Sensitivity analyses with distinct weighting protocols were conducted to evaluate the stability of the final results.

Results: Thirty potential users of a PCA data collection system were recruited in the study. The item "easy to use" had the highest median rank and received the heaviest mean weight among all items. MAU analysis showed that the PDA system had a higher utility score than that in the other 2 systems. Sensitivity analyses revealed that both inverse and reciprocal weighting processes favored the PDA system. High correlations between overall satisfaction and MAU scores from miscellaneous weighting protocols suggested a good predictive validity of our MAU-based questionnaire.

Conclusion: The PDA system was selected as the most favorable PCA data collection system by the MAU analysis. The item "easy to use" was the most important attribute of the PCA data collection system. MAU theory can evaluate alternatives by taking into account individual preferences of stakeholders and aid in better decision-making. [*J Chin Med Assoc* 2010;73(10):533–539]

Key Words: decision analysis, multi-attribute utility, optic card reader, patient-controlled analgesia, personal digital assistant

Introduction

Patient-controlled analgesia (PCA) is a highly effective and widely accepted means of relieving post-operative pain.[1,2] The data collected from PCA practice are valuable to clinicians because useful information can be generated through judicious data analyses.[3,4] A reliable and thorough data collection system is important for management of PCA. An ideal data collection system has to possess favorable characteristics such as reliability, manageability, and low cost. Although it is difficult to find a perfect data collection system for PCA, selecting an optimal system from available options is necessary. To select the most suitable PCA data collection system for daily practice, objective evaluation of each candidate system before further decision-making is required. However, it is not easy to reach a consensus among potential users of such systems because individual preferences can be very different. Therefore, a more efficient and objective evaluation method is essential to select the most acceptable PCA data collection system.

*Correspondence to: Dr Kuang-Yi Chang, Department of Anesthesiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, R.O.C.
E-mail: kychang@vghtpe.gov.tw • Received: April 14, 2010 • Accepted: July 2, 2010

To evaluate several alternatives, it is important to use a systematic approach to support decision-making processes. However, these processes can become fairly complicated if there are numerous factors to consider that are combined in different ways to produce various outcomes. For example, in choosing a PCA data collection system, alternative choices for various attributes should be compared. The relative contribution of each attribute to the overall decision should also be weighted. Multi-attribute utility (MAU) theory represents a group of methods to analyze situations and create evaluation processes.[5,6] It assesses individual preferences and constructs utility functions with mathematical methods to compare the weighted combination of attributes in evaluating alternatives. MAU theory has been effectively applied to some health-related behavior studies and medical decision-making, such as getting flu shots,[7,8] planning of emergency medical services,[9] purchase of ventilators,[10] and epidural labor analgesia.[11] In the current study, we used a MAU theory-based questionnaire to evaluate 3 PCA data collection systems: the personal digital assistant (PDA) system, the optic card reader (OCR) system and a traditional paper record. We then performed decision analysis on selecting an optimal PCA data collection system. To illustrate the process, a step-by-step procedure for creating a MAU-based decision analysis for selection of the PCA data collection system was provided. Sensitivity analysis was also conducted to evaluate the effects of distinct weighting processes on the overall scores.

Methods

Current situation analysis

This study was conducted in Taipei Veterans General Hospital, a tertiary medical center in Taiwan. There are approximately 5,000 PCA cases annually in our hospital. A PDA-based data collection system has been used for PCA practices since 2005 with the traditional paper recording system as a backup. Although the PDA system has operated well in the past, there have been increasing problems of malfunction in recent years. Thus, we conducted this study to determine which system should be developed and maintained in the future.

Participants

Participants were all potential users (named stakeholders in MAU analyses) of the PCA data collection system, including PCA team staff and residents in anesthesiology. The survey was conducted from January to April, 2009. All participants completed the questionnaire during this period.

Development of the MAU-based questionnaire

An expert committee was organized to develop a questionnaire based on MAU theory. The committee was composed of 4 members, including the leader of the PCA team and another 3 anesthesiologists. Following a literature review, open-ended discussions proceeded to formulate questions related to the PCA data collection system. All members were asked to discuss how to evaluate a PCA data collection system. New concepts about evaluation of the PCA data collection system proposed in each discussion were added to the preliminary questionnaire for the next discussion until no new issue was identified. After 3 conferences, we integrated 10 items to develop the main questionnaire for evaluation of the PCA data collection system.

The final version of the preliminary questionnaire was finished at the third meeting. Consensus on the content validity of the questionnaire was reached, and no redundancy or insufficiency of concepts was found. Appropriate wording, order, style, and semantics of the questionnaire were also verified. The final version yielded 10 items related to evaluation of the PCA collection system and 1 item for overall satisfaction with specific systems. A blank space was reserved at the beginning of each item for respondents to assign item weight to it. An additional item assessing overall satisfaction with a system was attached to the end of the questionnaire. Three systems were compared in the questionnaire, including the paper record, OCR and PDA. A pilot study was conducted to evaluate its reliability after construction of the questionnaire. The final version of questionnaire is presented in the Appendix.

Pilot study

Ten anesthetic residents and nurse anesthetist trainees were recruited in the pilot study. After explanation of the judgment task, participants were asked to respond to the 11 items in the questionnaire and assign item weight to the first 10. For each item, the participants judged each system on whether it conformed to the item statement or not and then answered to which extent they agreed using a Likert scale from l to 5. All participants in the pilot study were asked to repeat the questionnaire 1 week later to assess test–retest reliability. After completion of the pilot study, the collected data were submitted to reliability analysis. The Cronbach's α value of the first 10 items was 0.76, which indicated acceptable internal reliability.[12] The test–retest reliabilities for summated item score and item weight were 0.89 and 0.82, respectively. After confirmation of internal consistency and test–retest reliability of the questionnaire, the main study was conducted to evaluate the utility of the 3 PCA data collection systems.

Evaluation of the PCA data collection system

The primary objective of this phase was to perform a comprehensive evaluation of the utility of the 3 PCA data collection systems. The final version of the questionnaire was provided to every resident and each member of the PCA team. The participants assigned a utility score to each item with the method stated in the former section. A weighted utility score was calculated by the following procedures for each system. First, the respondent assessed the relative importance of the first 10 items and then assigned the rank to individual items according to the order of importance in which they were determined. The most important item would be assigned the rank of 1, the second most important item would be the rank of 2, and so on. After rank assignment, inverse coding was then performed to reverse the original rank order. For example, the original rank of 1 would be recoded to 10 and 2 would become 9. Third, these recoded numbers were divided by their sum as the weight of the individual item for each participant. After completion of the weighting process, the utility score of each item was multiplied by its weight, and then the weighted score of each item was summed up to be a total weighted score for each PCA data collection system.[5] The acquired summation score for each system was then submitted to further analysis.

Statistical analyses

Descriptive summaries of original score and weight of individual items (means and standard deviations) are presented for the 3 systems. Statistical comparisons among systems were performed with the Kruskal–Wallis test. If significant differences were found among the 3 systems, *post hoc* analyses were conducted with Dunn's multiple comparison tests. Since different weighting processes might influence the final result, sensitivity analysis with equal weight and rank reciprocal weighting was also used to evaluate the stability of the final results.[5] The rank reciprocal weighting method used the reciprocal of item rank divided by the sum of these reciprocals as the weight of each individual item. Subgroup analyses of the MAU score for PCA team members and residents were also performed. Spearman rank correlation coefficients between overall satisfaction and MAU score estimated from different weighting methods were calculated to evaluate the predictive validity of miscellaneous weighting procedures. All data were analyzed by the statistical software SPSS 15.0 (SPSS Inc., Chicago, IL, USA).

Results

There were 30 potential users of the PCA data collection system recruited in the study, including 6 PCA team members and 24 residents in anesthesiology. Table 1 illustrates the results of mean score comparisons among the 3 systems. There was no significant difference in "fewer recording errors" among the 3 systems. Mean scores of the other items were significantly different among the 3 systems. The traditional paper recording system had the highest scores in the items "easy to use", "reliability", "lower establishment cost", and "lower maintenance cost". The PDA system had the highest scores in the items "easy to manage data" and "procedure simplification". The OCR system did not have a high score in any of the items. For the items "easy to record" and "less patient interview time", the paper recording and PDA systems had significantly higher scores than those in the OCR system. For the item "fewer input errors", the PDA and OCR systems obtained higher scores than those in the paper

Table 1. Mean score of all items in the multi-attribute utility questionnaire for the 3 patient-controlled analgesia data collection systems*

	Paper record	PDA	OCR	$p^\dagger$
Q1. Easy to use	4.3 ± 0.9	3.2 ± 1.1	3.1 ± 1.2	< 0.001
Q2. Easy to record	3.6 ± 1.1	3.9 ± 1.2	2.8 ± 1.1	0.001
Q3. Reliability	4.2 ± 0.9	3.0 ± 1.2	3.2 ± 1.1	< 0.001
Q4. Lower establishment cost	4.4 ± 0.8	2.1 ± 0.9	2.8 ± 1.0	< 0.001
Q5. Lower maintenance cost	4.4 ± 0.9	2.0 ± 0.9	2.7 ± 1.2	< 0.001
Q6. Easy to manage data	2.5 ± 1.3	4.3 ± 1.0	3.7 ± 1.3	< 0.001
Q7. Less patient interview time	3.4 ± 1.0	3.5 ± 1.1	2.8 ± 1.1	0.042
Q8. Fewer recording errors	3.2 ± 1.1	3.4 ± 1.1	2.9 ± 1.2	0.320
Q9. Fewer input errors	2.8 ± 1.3	3.8 ± 1.3	3.4 ± 1.4	0.027
Q10. Procedure simplification	2.3 ± 1.1	4.1 ± 1.2	3.3 ± 1.3	< 0.001
Overall satisfaction	6.2 ± 2.0	7.1 ± 1.8	5.9 ± 2.4	0.129

**Data presented as mean ± standard deviation; †Kruskal–Wallis test. PDA = personal digital assistant; OCR = optic card reader.*

recording system. Among the 3 systems, the PDA system had the highest score in overall satisfaction, but this was not significantly different between the systems ($p = 0.13$).

Table 2 shows the results of the weighting process for individual items. The original item ranks are presented as median with interquartile range. In general, the item "easy to use" had the highest median rank and received the heaviest mean weight among all items, followed by "easy to record", "procedure simplification", and "easy to manage data". The items "lower establishment cost" and "lower maintenance cost" received the least weight among all items.

Table 3 exhibits the MAU of distinct PCA data collection systems and sensitivity analyses with different weighting processes. For inverse and reciprocal weighting procedures, the PDA system had a higher MAU than the other 2 systems. The paper recording system had the highest MAU in conditions of equal weight. However, there was no significant difference in MAU scores among the 3 systems.

Table 4 shows the subgroup analysis of MAU scores of the 3 systems and sensitivity analyses with distinct weighting methods. There was no significant difference in MAU scores from the 3 weighting processes in the subgroup composed of residents. However, there were significant differences in MAU scores among the 3 systems in the PCA team staff. Regardless of which weighting method was used, the paper recording system had a significantly higher MAU score than the OCR system ($p < 0.05$ by Dunn's multiple comparison test). MAU scores of the PDA system were not significantly different from those of the paper recording system regardless of the weighting processes used.

Table 5 shows the correlation matrix between overall satisfaction and MAU score from miscellaneous weighting methods. All Spearman rank correlation coefficients in the matrix were statistically significant (all $p < 0.001$). The MAU score from the inverse weighting process had the highest correlation with overall satisfaction ($\rho = 0.78$).

Discussion

In this study, we demonstrated that MAU theory is a useful methodology to help make better decisions. The theory incorporated input from various stakeholders, identified and weighted attributes that were important in the decision and alternative options, and finally provided an overall score that indicated the optimal decision. Several studies have shown that it can be successfully applied to decision analysis or decision-making. For example, Chatburn and Primiano used the MAU model to create a capital purchase plan for purchasing a mechanical ventilator suitable for use in a hospital intensive care unit.[10] Baker et al applied the MAU model to determine important inputs in the planning for emergency medical services.[9] Chang et al also applied MAU theory to identify factors affecting attitude toward labor epidural analgesia and to predict parturients' pre-labor and labor decisions on epidural analgesia.[11] Our study is

Table 3. Calculation of the multi-attribute utility score for distinct patient-controlled analgesia data collection systems with different weighting methods*

Weighting method	Paper record	PDA	OCR	$p^{\dagger}$
Inverse	3.38 ± 0.70	3.55 ± 0.75	3.09 ± 0.97	0.17
Reciprocal	3.37 ± 0.81	3.56 ± 0.74	3.09 ± 0.98	0.19
Equal	3.54 ± 0.59	3.34 ± 0.71	3.06 ± 0.92	0.17

Data presented as mean ± standard deviation; †Kruskal–Wallis test. PDA = personal digital assistant; OCR = optic card reader.

Table 2. Descriptive results of the weighting process for individual items

	Median	Interquartile range	Weight	SD of weight
Q1. Easy to use	2	1.0–5.5	0.133	0.059
Q2. Easy to record	4	2.0–5.5	0.128	0.040
Q3. Reliability	7	5.0–8.0	0.078	0.035
Q4. Lower establishment cost	9	7.5–10.0	0.056	0.048
Q5. Lower maintenance cost	9	5.5–10.0	0.061	0.050
Q6. Easy to manage data	5	2.5–6.5	0.117	0.043
Q7. Less patient interview time	5	3.0–8.0	0.106	0.049
Q8. Fewer recording errors	5	3.0–7.0	0.109	0.050
Q9. Fewer input errors	6	4.0–7.5	0.093	0.042
Q10. Procedure simplification	4	2.5–7.0	0.118	0.043

SD = standard deviation.

Table 4. Subgroup analysis of the multi-attribute utility score for distinct patient-controlled analgesia (PCA) data collection systems with different weighting methods*

Subgroup	Weighting method	Paper record	PDA	OCR	$p^{\dagger}$
Residents ($n = 23$)	Inverse	3.26 ± 0.67	3.59 ± 0.73	3.35 ± 0.78	0.20
	Reciprocal	3.26 ± 0.79	3.58 ± 0.77	3.36 ± 0.79	0.38
	Equal	3.42 ± 0.54	3.40 ± 0.66	3.29 ± 0.76	0.92
PCA team ($n = 6$)	Inverse	3.83 ± 0.67	3.38 ± 0.86	2.08 ± 1.03	0.024
	Reciprocal	3.77 ± 0.80	3.49 ± 0.63	2.06 ± 0.99	0.011
	Equal	3.98 ± 0.62	3.10 ± 0.88	2.20 ± 1.04	0.024

*Data presented as mean ± standard deviation; †Kruskal–Wallis test. PDA = personal digital assistant; OCR = optic card reader.

Table 5. Spearman correlation coefficient matrix between overall satisfaction and the multi-attribute utility score from miscellaneous weighting methods

	Overall satisfaction	Inverse weight	Equal weight
Inverse weight	0.78		
Equal weight	0.76	0.91	
Reciprocal weight	0.70	0.96	0.84

All $p < 0.001$.

consistent with the other studies in demonstrating the usefulness and versatility of MAU theory in medical decision-making.

According to our results, the PDA system had higher MAU scores compared with the other 2 systems for the inverse and reciprocal weighting processes, and the paper recording system had the highest MAU scores under the condition of equal weight, although there was no significant difference in MAU scores among the 3 systems. Based on the MAU analysis, users of the PCA data collection system preferred the PDA system to the other 2 systems. Moreover, comparing weighting results of individual items, we found that users of the PCA data collection system reached some consensus on the importance of each item. Obviously, each item had a different significance for system users, and the relative importance of each item should be taken into account to avoid biased interpretation of simply summated scores without individual item weighting. For example, the item "easy to use" had the highest median rank and received the heaviest mean weight among all items. In contrast, the item "lower establishment cost" or "lower maintenance cost" received the least mean weight among all items for most users. For most users, an "easy to use" system is more favorable than a "low cost" system. In addition, sensitivity analysis in our study revealed that summated scores without weighting of individual items would favor the paper recording system. In fact, the PDA system was the most favorable after taking the relative importance of items into consideration, regardless of which weighting processes were used. MAU analysis provided a robust way to evaluate the utility of each system with the responses of the stakeholders.

Based on the subgroup analysis of MAU scores and sensitivity analyses with distinct weighting methods, there was no significant difference in MAU scores among the 3 systems in the residents group; however, there was a significant difference in MAU scores among PCA team staff. The paper recording system had significantly higher MAU scores than those of the OCR system regardless of different weighting processes. Several reasons may explain this finding. First, the PCA team staff is responsible for most PCA daily practices in our hospital, including patient interviews, dose adjustment and data collection. The PCA team staff is accustomed to a traditional paper recording system in their daily work. The introduction of the OCR system challenged their common habits of data recording in daily practice, and therefore, they had to learn how to use the new system and adapt themselves to the new system. Thus, they were reluctant to accept a new system. Second, some senior PCA team staff complained that the words and blank spaces on the optic card were too small to identify and would increase recording errors; presbyopia increases the difficulty of using with the OCR system. Moreover, high correlations between overall satisfaction and MAU scores from miscellaneous weighting methods suggested good predictive validity of our MAU-based questionnaire. The correlation analysis also revealed that the inverse weighting method was better than the other 2 methods because it had a higher correlation with overall satisfaction than the other 2 methods.

There are some limitations to our study. First, the ability to generalize from our results is limited because this was a single-center study. The PCA data collection system most suitable for our situation might not be a common solution for other centers, but we have provided a useful approach to evaluate the PCA data collection system with a questionnaire developed based on MAU theory. Other centers should also evaluate their systems with a similar approach. Second, there was no significant difference in MAU scores of the 3 systems. This may be due to the limited sample size of our study. One of the aims of the MAU model was to help make better decisions. Since we included all potential users of the PCA data collection system, the results are still of clinical importance. They could be used to help determine which system should be used in light of the consensus of all stakeholders.

In conclusion, the PDA system was selected as the most favorable PCA data collection system using the MAU analysis. The item "easy to use" was the most important feature of the PCA data collection system. MAU theory can evaluate alternatives by taking into account individual preferences of stakeholders and aid in better decision-making.

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Appendix. Questionnaire for evaluation of the patient-controlled analgesia data collection system

1. Please judge each system on whether it conforms to an item statement and then respond in integer values from 1 to 5 to reflect how it agrees with the statement.
2. Please assess overall satisfaction with a system and then respond in integer values from 1 to 10 to reflect your satisfaction with the system.
3. Please assess relative importance of the first 10 items and then assign a rank (1 to 10) to the item in accordance with the order of importance.

Importance rank	Item statement	Paper record	PDA	OCR
	The system is easy to use			
	The system is easy to record			
	The system is reliable			
	Construction cost of the system is low			
	Maintenance cost of the system is low			
	The system is easy for data management			
	The system can save interview time			
	The system can reduce input errors			
	The system can reduce transcription errors			
	The system can simplify data collection			
Overall satisfaction with the system (1–10)				

PDA = personal digital assistant; OCR = optic card reader.