Rule-Based Evaluation for the Patient-Controlled Analgesia Clinical Effectiveness

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Introduction: The self-regulated patient-controlled analgesia (PCA) has become an established procedure for clinical pain relief through the electric-mechanical pumping control to deliver a bolus dose and a background infusion. Since the pain is subjective sense and pain measurement relies on the verbal report of patients, it is difficult to quantify and evaluate the clinical effectiveness of PCA therapy.[1] The PCA logs that stored the drug delivery settings, patients' demand/delivery condition, and therapeutic history were often neglected by most hospitals due to the shortage of manpower. Therefore, a rule-based evaluation of clinical effectiveness for miscellaneous PCA protocols using a novel index based on Fuzzy logic model is proposed to evaluate PCA pain care quality. Firstly, the proposed system intends to explore the relationship between patients' demand and analgesic delivery (termed D/D ratio) during the therapy. Through a fuzzy-ruled classification and discrimination, a referable PCA clinical effectiveness index that reveals therapeutic effectiveness of PCA therapy will be provided to the anesthesiologists to realize the patient's pain relief profile and recovery status.

Methods: Inpatients who adopted the PCA therapy assumed the pain shall be adequately relieved. However, many still experienced certain level of pain during the therapy that resulted in the decline of patient's postoperative recovery and dissatisfaction about PCA service. In order to realize the pain relief profile during the PCA therapy, the analgesic demand and delivery events with corresponding timestamps were extracted from the PCA microcomputer log. The D/D ratio which equals to the demand counts divided by the delivery counts was used as a major input. The time series of D/D ratio will be pre-processed through the aggregation technique of sliding window. A four-hour window is adopted to calculate the D/D ratio and the window slides every one hour. This means a 72-hour PCA therapy will be aggregated into 69 dataset of D/D ratio. During our previous study in 2006~2009, the proposed PCA EDC (Electronic Data Collection) system had collected over 16,000 patients' clinical data.[2] Patients who adopted orthopedic surgery and IV-PCA therapy with constant 0.1~0.2 ml/hr background infusion were selected as samples in this study. In order to obtain a reasonable PCA clinical effectiveness index, we chose five linguistic levels of the D/D ratio as fuzzifier inputs. They are Increase Big (IB), Increase Small (IS), Zero (Z), Decrease Small (DS), and Decrease Big (DB) respectively. In addition, each level is further classified into three categories with varying extents: Big, Medium, and Small. The fuzzy inference engine and the defuzzifier were cooperated with opinions of the anesthesiologists. The generated PCA clinical effectiveness index will give a suitable appraisal after the PCA therapy, and the overview is illustrated in Figure 1.
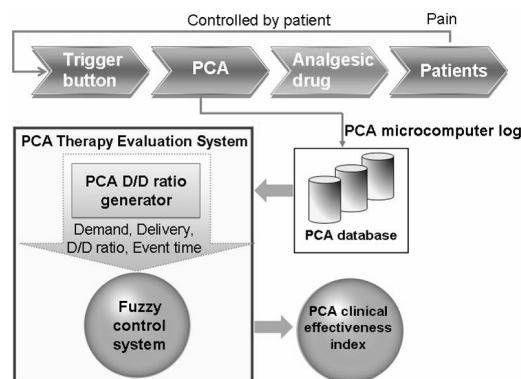

Figure 1. PCA clinical effectiveness index is generated to give appraisal after PCA therapy

Results: The statistics of D/D ratio patterns collected from a 4-hour window that slides every 1-hour is shown in Table 1. The D/D ratio profile of a 48-hour PCA therapy can be classified into 6 patterns: (1)Flat profile; (2) Descending profile; (3) Middle-High profile with peak in 12~24 hour therapy; (4) Middle-High profile with peak in 24~36 hour therapy; (5) Ascending profile; (6) M-Peak profile.

The PCA clinical effectiveness index graded the PCA therapeutic satisfaction into 5 levels, and they are "Best", "Good", "Normal", "Bad", and "Worst", respectively. The statistics is drawn in Figure 2. The PCA satisfaction is 79% that summed the level of "Best", "Good", and "Normal". The result can faithfully reflect the PCA satisfaction from the questionnaire of the PCA nurses' daily visitation.

Table 1. Six patterns of D/D ratio based on sliding window

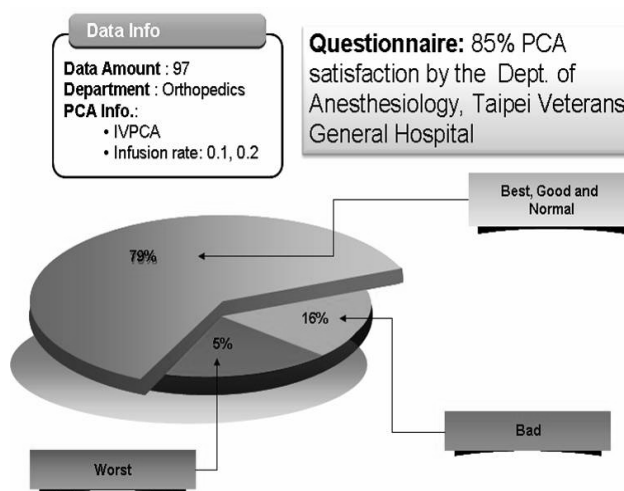| No.	Pattern Type	Sample Amount	Percent
1	Flat Profile : Normally Distributed (D/D Ratio=1~2)	30	31%
2	Decending Profile : Peak Lies in 1-12 Hour	28	29%
3	Middle-High Profile : Peak Lies in 12-24 Hour	19	20%
4	Middle-High Profile : Peak Lies in 24-36 Hour	7	7%
5	Ascending Profile : Peak Lies in 36-48 Hour	8	8%
6	M-Peak Profile : Multiple Peaks	5	5%
	Summation	97	100%

Figure 2. The satisfaction statistics of PCA clinical effectiveness index

Discussion: Essentially, the best satisfaction of PCA therapy lies in the D/D ratio approaching 1 because one demand earns one delivery of drug injection and the analgesic effect happens to relieve patient's pain.[3] Most orthopedic postoperative patients were arranged to take off-bed rehabilitation in the second day after surgery which led to the middle-high profile of D/D ratio.

The PCA clinical effectiveness index and the pain relief profile offer doctors important treatment reference, especially for the patients with second or recurrent surgery. In addition, the pain relief profile on different divisions of medicine and various surgical sites are classified and summarized into useful information for doctors. However, the assessment of PCA clinical effectiveness exploited the offline data mining methods to evaluating the clinical effectiveness. An on-line PCA effectiveness evaluation is going to be planned to perform better therapeutic quality.

References:

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3. Chang, K.-Y., et al., *Determinants of Patient-controlled Epidural Analgesia Requirements: A Prospective Analysis of 1753 Patients.* The Clinical Journal of Pain, 2006. 22(9): p. 751-756 10.1097/01.ajp.0000210924.56654.03.