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# Pain monitoring strategies in ICU patients on mechanical ventilation: A comparative analysis

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ABSTRACT

Background: The pain experienced by patients in Intensive Care Units (ICUs) can exacerbate the stress response if it is not adequately monitored and treated. This can trigger a cascade of psychological and physiological events, including prolonged mechanical ventilation, longer ICU stays, increased morbidity and mortality, and a decreased quality of life.

Material and Methods: This observational study was conducted in a critical care unit with a sample size of 96 patients, divided into two groups of 48 patients each. One group was designated as the cases, where the Critical Care Pain Observation Tool (CPOT) was applied, and the other group served as the controls, where the CPOT was not applied. The study included patients who were tracheally intubated, required mechanical ventilation, and sedation, and had an ICU stay of more than 24 hours. These patients were recruited on the first day of tracheal intubation. The level of sedation was maintained at a Ramsay sedation score greater than 3. The CPOT and physiological variables were evaluated both at rest and during painful procedures. Data collection occurred at rest, during tracheal suctioning, and 20 minutes after patient positioning.

Results: The study found a significant negative correlation between the CPOT and the Ramsay Sedation Scale. While the CPOT total scores were higher during procedures, this increase was not statistically significant. However, the mortality rate was lower in the case group (7 out of 48) compared to the control group (17 out of 48).

Conclusion: The findings of this study conclude that the CPOT possesses good psychometric properties and can be effectively adopted to standardize pain assessment for ventilated patients who are unable to self-report their pain.

**Keywords:** analgesia, Critical Care Pain Observation Tool (CPOT), Intensive Care Unit (ICU), pain, stress

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## INTRODUCTION

For many decades, patients in Intensive Care Units (ICUs) have consistently reported pain as one of the most distressing symptoms, despite extensive research aimed at alleviating it [1]. The most painful and distressing procedures for adult ICU patients include being turned in bed, undergoing tracheal suctioning, the presence of chest tubes, and the changing of dressings [2]. Inadequate management of pain can worsen the stress response, leading to a cascade of psychological and physiological events. This can result in prolonged mechanical ventilation, extended ICU stays, increased risk of morbidity and mortality, and a diminished quality of life [3]. Barriers to pain management in these intensive care unit patients include inability to communicate verbally, life-threatening illness or injury, lack of pain management education for health care providers, inconsistency in pain management protocols, and system related barriers [4, 5]. Thus, appropriate pain relief helps in minimizing the above-mentioned adverse outcomes. The first step in pain management is the appropriate and routine assessment of the presence and severity of pain [6]. The most vulnerable individuals to inadequate pain management are those who cannot self-report their pain. In adult intensive care units, approximately one-third of critically ill patients are unable to communicate their pain levels. Additionally, 40% of patients who can report their pain find it challenging to do so accurately using self-rating scales like the Numeric Rating Scale (NRS). Consequently, many patients may benefit from a behavioural pain scale, such as the Critical Care Pain Observation Tool (CPOT) (Figure 1 and table 1). This study aims to evaluate the effectiveness of the CPOT in assessing pain and its impact on patient outcomes among mechanically ventilated adult ICU patients [7].

## MATERIALS AND METHODS

After obtaining institutional ethical committee clearance (Ref. code: 102nd ECM II B-Thesis/P117), this prospective observational comparative study was conducted. Based on a previous study, a total of 96 critical care patients were included in this study [8]. The study was done in a trauma ventilator unit which has 18 beds. Out of 96 patients enrolled in the study 48 (50.0%) patients were evaluated with Critical Care Pain Observation Tools (CPOT) were classified as cases and the rest 48 (50.0%) patients CPOT was not applied were classified as controls. Patients of 18 years old and either gender were included in this study after obtaining written informed consent from a

relative or guardian. The patients who were on ventilation with endotracheal intubation and on sedation for more than 24 hours were included in the study. Patients receiving muscle relaxants, on chronic analgesic therapy and history of psychiatric illness were excluded. The sedation was monitored using Ramsay sedation score and kept more than 3 for all patients. After recruitment, all patients were assessed for pain using both a physiological monitor (measuring blood pressure and heart rate) and the CPOT. The CPOT and physiological variables were evaluated at rest and during painful procedures to gauge the responsiveness of the CPOT. The two chosen painful procedures were Endotracheal Tube (ETT) suctioning and patient positioning (defined as the movement involved in shifting the patient in bed). The patient was observed at rest for 1 minute to get a baseline value of the CPOT. Then, the patient was observed during nociceptive procedures (e.g., positioning, suctioning), to detect any changes within the patient's behaviours to pain. The data were collected at rest, at tracheal suctioning, 20 minutes later after positioning of the patient. The data was summarized as mean ± standard deviation. To test the significance of two means, the student 't' test was used. The correlations between the studied parameters were analysed using Pearson's correlation. Coefficient $p<0.05$ was considered statistically significant. Comparison between the groups for sedation score was done using Mann-Whitney U test.

| | Score | Description |
|---|---|---|
| **Facial expression** | Relaxed, neutral 0 | No muscle tension observed. |
| | Tense 1 | Presence of frowning, brow lowering, orbit tightening and levator contraction or any other change (e.g. opening eyes or tearing during nociceptive procedures) Facial expression. |
| | Grimacing 2 | All previous facial movements plus eyelid tightly closed (the patient may present with mouth open or biting the endotracheal tube) |
| **Body movements** | Absence of movements 0 or normal position | Does not move at all (doesn't necessarily mean absence of pain) or normal position (movements not aimed toward the pain site or not made for the purpose of protection) |
| | Protection 1 | Slow, cautious movements, touching or rubbing the pain site, seeking attention through movements. |
| | Restlessness/Agitation 2 | Pulling tube, attempting to sit up, moving limbs/thrashing, not following commands, striking at staff, trying to climb out of bed |
| **Compliance with the ventilator** (intubated patients) Or **Vocalization** (extubated patients) | Tolerating ventilator or movement 0 | Alarms not activated, easy ventilation |
| | Coughing but tolerating 1 | Coughing, alarms may be activated but stop spontaneously. |
| | Fighting ventilator 2 | Asynchrony: blocking ventilation, alarms frequently activated . |
| | Talking in normal tone or no sound 0 | Talking in normal tone or no sound |
| | Sighing, moaning 1 | Sighing, moaning |
| | Crying out, sobbing 2 | Crying out, sobbing |
| **Muscle tension** : Evaluation by passive flexion and extension of upper limbs when patient is at rest or evaluation when patient is being turned | Relaxed 0 | No resistance to passive movements |
| | Tense, rigid 1 | Resistance to passive movements |
| | Very tense or rigid 2 | Strong resistance to passive movements or incapacity to complete them. |
| **Total** | ----------/ 08 | |

**Fig. 1.** Critical pain observation tool

**Tab. 1.** Ramsay sedation score

| Score | Criteria |
|---|---|
| 1 | Patient is anxious and agitated or restless, or both |
| 2 | Patient is co-operative, oriented, and tranquil |
| 3 | Patient responds to commands only |
| 4 | Patients exhibits brisk response to light glabeller tap or loud auditory stimulus |
| 5 | patient exhibits a sluggish response to light glabeller tap or loud auditory stimulus |
| 6 | Patient exhibits no response |

## RESULTS

In this study we had patients aged 18 years to 80 years with a mean age of 37.89 years ± 15.93 years. The mean age in the control group was 38.21 years ± 15.20 years and was higher than that of the other group 37.56 years ± 16.79 years. Although there was a difference, it was statistically insignificant (p=0.844). A total of 45 (46.9%) patients were female and 51 (53.1%) were male in this study and the difference was statistically insignificant (p=0.152). Heart Rate (HR) and Blood Pressure (BP) of patients were noted at rest, at positioning and at endotracheal tube suctioning during their stay in critical care. At rest, cases and controls had compa-rable heart rate at all the observation time periods except at day 5 when heart rate of Controls was found to be significantly higher than that of cases (Table 2).

**Tab. 2.** Between Group Comparison of HR (at rest) of patients at different time interval

| Day of Obs. | Cases | | | Controls | | | Student 't' Test | |
|---|---|---|---|---|---|---|---|---|
| | No. of Pts | Mean | SD | No. of Pts | Mean | SD | 't' | 'p' |
| Day 1 | 48 | 82.1 | 2.1 | 48 | 83.2 | 5.5 | -1.33 | 0.19 |
| Day 2 | 48 | 80.1 | 4.8 | 48 | 80.6 | 7.5 | -0.39 | 0.7 |
| Day 3 | 48 | 80.7 | 4.4 | 48 | 82.8 | 7.6 | -1.68 | 0.1 |
| Day 4 | 48 | 81.5 | 4.6 | 48 | 82 | 8.7 | -0.29 | 0.77 |
| Day 5 | 47 | 82.2 | 5.9 | 45 | 84.9 | 6.7 | -2.07 | 0.04 |
| Day 6 | 45 | 82.5 | 6 | 42 | 83 | 6.6 | -0.31 | 0.76 |
| Day 7 | 42 | 80.6 | 7.6 | 38 | 82.4 | 7.1 | -1.12 | 0.27 |
| Day 8 | 31 | 81.9 | 7.1 | 34 | 83.8 | 6.4 | -1.13 | 0.26 |
| Day 9 | 22 | 80.7 | 7.2 | 32 | 81.9 | 9.2 | -0.52 | 0.61 |
| Day 10 | 16 | 80.6 | 7.1 | 28 | 82.9 | 9.6 | -0.81 | 0.42 |

During both positioning and ETT suctioning, the heart rates of the cases and controls were comparable throughout all periods of observation (day 1 to day 10). After repositioning the patient, heart rates were higher compared to resting levels in both groups. However, no statistically significant changes in heart rate were observed at rest following repositioning. Similarly, heart rates were elevated after ETT suctioning compared to rest in both groups, with comparable heart rate changes observed at rest following ETT suctioning across all periods of observation.

At rest Systolic BP (SBP) of cases and controls were found to be comparable at all the periods of observation. We did not notice any statistical difference between the groups in SBP recordings after positioning and post ETT suctioning during the study period (day 1 to day 10). The SBP was found to be higher after positioning and post ETT suctioning than that at resting position among both cases and controls. A comparable change in SBP at rest was observed in both cases and controls after positioning and post ETT suctioning at all the periods of observation.

On day 8 at rest Diastolic BP (DBP) of controls was found to be significantly higher than that of cases (Table 3). On other days of the observational periods, at rest DBP of cases and controls were found to be comparable. Among two groups, controls had significantly higher DBP at positioning as compared to cases at all the periods of observation except day 1 and day 3 as shown in table 4. The controls had significantly higher diastolic BP after suction as compared to cases at all the periods of observation except day 1 and day 5 as shown in table 5. Diastolic Blood Pressure (DBP) after positioning was consistently higher than at rest in both cases and controls at all observation periods, except on day 10 for the cases. The change in DBP at rest during positioning was similar for both groups, with exceptions on day 5, day 6, and 10 days. Following ETT suctioning, DBP was elevated compared to resting levels in both groups across all observation periods. Significant differences in the change in resting DBP between cases and controls were observed only on days 6, day 7, and day 10. Additionally, the Ramsay sedation score for cases was significantly higher than that for controls throughout all observation periods, as detailed in table 6. The Critical Care Pain Observation Tool (CPOT) of cases recorded at different time periods is shown in Figure 2. Duration of stay in ICU was higher among controls as compared to cases (10.69 days ± 4.80 days *vs.* 9.67 days ± 4.36 days) but this difference was statistically insignificant. In both groups, proportion of patients discharged after successful treatment was similar (2 patients i.e. 4.2%), proportion of patients transferred to ward from ICU were higher among cases as compared to controls i.e. 39 (81.3%) *vs.* 29 (60.4%) (Figure 3). The proportion of mortality was higher among controls as compared to cases i.e., 7 (35.4%) *vs.* 17 (14.6%). Although the difference was seen, it is statistically insignificant (p=0.060) (Figure 4). Correlation of CPOT with vital parameters HR, SBP and DBP was not found to be significant at majority of the periods of observation. Significant correlation between CPOT and sedation score was observed at all the periods of observation except on day 10 at rest and on post positioning.

**Tab. 3.** Between group comparison of DBP (at rest) of patients at different time interval

| Day of Obs. | Cases | | | Controls | | | Student 't' Test | |
|---|---|---|---|---|---|---|---|---|
| | No. of Pts | Mean | SD | No. of Pts | Mean | SD | 't' | 'p' |
| Day 1 | 48 | 70.04 | 6.22 | 48 | 71.46 | 5.58 | -1.174 | 0.243 |
| Day 2 | 48 | 68.75 | 5.65 | 48 | 69.63 | 7.2 | -0.662 | 0.509 |
| Day 3 | 48 | 67.13 | 6.28 | 48 | 68.54 | 6.73 | -1.066 | 0.289 |
| Day 4 | 46 | 69.78 | 5.77 | 48 | 71.33 | 6.29 | -1.244 | 0.217 |
| Day 5 | 46 | 70.78 | 6.58 | 45 | 72.98 | 6.28 | -1.628 | 0.107 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Day 6 | 43 | 67.77 | 4.62 | 42 | 68.1 | 6.21 | -0.276 | 0.783 |
| Day 7 | 42 | 71.33 | 5.03 | 38 | 72.79 | 6.81 | -1.095 | 0.277 |
| Day 8 | 31 | 67.74 | 4.84 | 34 | 70.59 | 5.45 | -2.218 | 0.03 |
| Day 9 | 22 | 71.27 | 7.6 | 32 | 72.44 | 5.37 | -0.661 | 0.512 |
| Day 10 | 16 | 70.75 | 7.76 | 28 | 71.57 | 8.32 | -0.323 | 0.748 |

**Tab. 4.** Between group comparison of DBP (Position) of patients at different time interval

| Day of obs. | Cases | | | Controls | | | Student 't' test | |
|---|---|---|---|---|---|---|---|---|
| | No. of Pts | Mean | SD | No. of Pts | Mean | SD | 't' | 'p' |
| Day 1 | 48 | 74.63 | 6.08 | 48 | 77.31 | 7.44 | -1.937 | 0.056 |
| Day 2 | 48 | 72.83 | 4 | 48 | 76.33 | 7.37 | -2.892 | 0.005 |
| Day 3 | 48 | 78.71 | 9.8 | 48 | 78.88 | 10.35 | -0.081 | 0.936 |
| Day 4 | 48 | 76.46 | 7.36 | 48 | 80.58 | 9.09 | -2.443 | 0.016 |
| Day 5 | 47 | 77.06 | 7.77 | 45 | 84.36 | 11.37 | -3.605 | 0.001 |
| Day 6 | 45 | 76 | 7.64 | 42 | 82.19 | 11.74 | -2.935 | 0.004 |
| Day 7 | 42 | 75.05 | 6.25 | 38 | 79.16 | 8.89 | -2.41 | 0.018 |
| Day 8 | 31 | 73.35 | 7.74 | 34 | 80.53 | 8.21 | -3.616 | 0.001 |
| Day 9 | 22 | 76.73 | 8.13 | 31 | 82.77 | 6.21 | -3.07 | 0.003 |
| Day 10 | 16 | 65.38 | 8.97 | 28 | 80.36 | 11.29 | -4.545 | <0.001 |

**Tab. 5.** Between group comparison of DBP (at suction) of patients at different time interval

| Day of Obs. | Cases | | | Controls | | | Student 't' Test | |
|---|---|---|---|---|---|---|---|---|
| | No. of Pts | Mean | SD | No. of Pts | Mean | SD | 't' | 'p' |
| Day 1 | 48 | 85.02 | 7.89 | 48 | 87.52 | 5.88 | -1.761 | 0.082 |
| Day 2 | 48 | 77.63 | 8.82 | 48 | 81.83 | 9.75 | -2.218 | 0.029 |
| Day 3 | 48 | 84.21 | 4.64 | 48 | 87.5 | 6.98 | -2.721 | 0.008 |
| Day 4 | 48 | 84.08 | 5.55 | 48 | 87.96 | 7.82 | -2.799 | 0.006 |
| Day 5 | 47 | 85.53 | 6.62 | 45 | 87.33 | 11 | -0.956 | 0.342 |
| Day 6 | 45 | 83.73 | 6.35 | 42 | 89.95 | 6.62 | -4.474 | <0.001 |
| Day 7 | 42 | 85.1 | 6.93 | 38 | 90.37 | 7.08 | -3.364 | 0.001 |
| Day 8 | 31 | 85.81 | 8.83 | 34 | 90.18 | 4.71 | -2.521 | 0.014 |
| Day 9 | 22 | 84.18 | 7.27 | 31 | 88.84 | 8.14 | -2.142 | 0.037 |
| Day 10 | 16 | 73.88 | 8.72 | 28 | 84.43 | 10.74 | -3.346 | 0.002 |

**Tab. 6.** Between group comparison of sedation score (RAS) (Mann-Whitney U test)

| Days | Cases | | | | Control | | | | Statistical Significance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Md | Mn | SD | No. | Md | Mn | SD | z | p |
| Day 1 | 48 | 4 | 3.54 | 0.5 | 48 | 3 | 3.02 | 0.91 | -3.003 | 0.003 |
| Day 2 | 48 | 4 | 3.65 | 0.56 | 48 | 2 | 2.08 | 0.65 | -7.935 | <0.001 |
| Day 3 | 48 | 4 | 3.79 | 0.77 | 48 | 2 | 2.06 | 0.89 | -7.225 | <0.001 |
| Day 4 | 48 | 4 | 4.15 | 0.65 | 48 | 2 .00 | 2.48 | 0.95 | -7.076 | <0.001 |
| Day 5 | 47 | 5 | 4.53 | 0.65 | 45 | 3 | 3.04 | 0.8 | -6.98 1 | <0.001 |
| Day 6 | 45 | 4 | 4.16 | 0.85 | 42 | 2 | 2.55 | 1.02 | -6.18 | <0.001 |
| Day 7 | 42 | 4 | 4.1 | 0.96 | 38 | 2 .00 | 2.29 | 0.87 | -6.439 | <0.001 |
| Day 8 | 31 | 5 | 4.84 | 0.45 | 34 | 3 | 3 | 0.74 | -6.867 | <0.001 |
| Day 9 | 22 | 4 | 4.14 | 0.77 | 32 | 2 .00 | 2.31 | 0.69 | -5.674 | <0.001 |
| Day 10 | 16 | 5 | 4.88 | 0.34 | 28 | 3 | 3.18 | 0.98 | -4.842 | <0.001 |

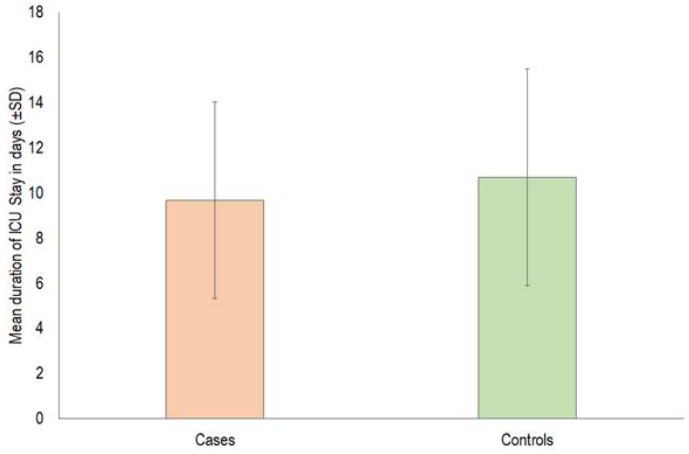


**Fig. 2.** Comparison of duration of intensive care unit stay in cases and controls

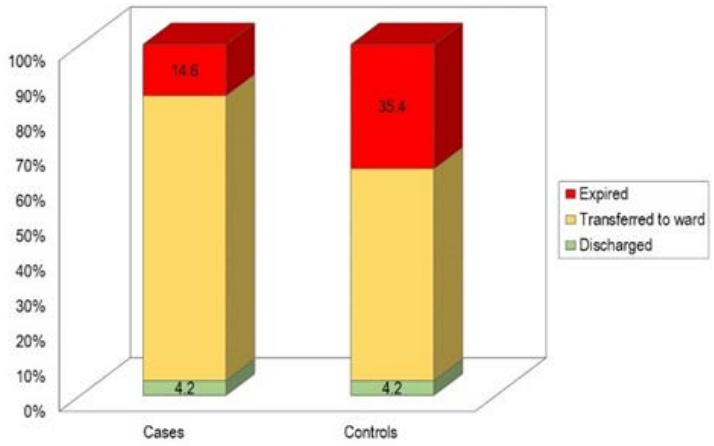


**Fig. 3.** Comparison of final outcome of cases and controls

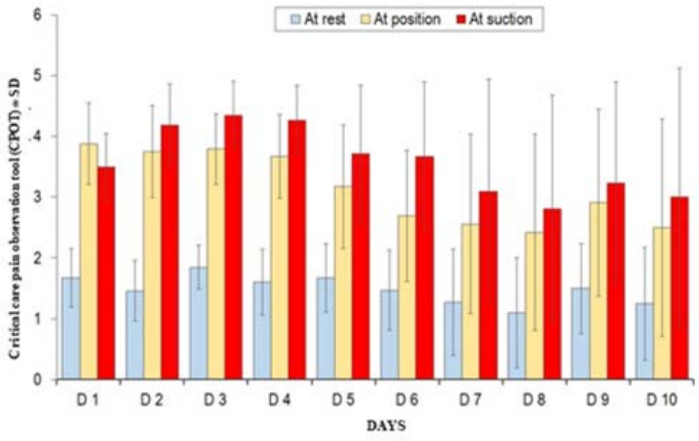


**Fig. 4.** Critical care pain observation tool scoring details in case group at all study duration

## DISCUSSION

Despite extensive research over several decades, pain remains a significant issue for critically ill patients throughout their stay in the Intensive Care Unit (ICU) [9]. A recent World Health Organization (WHO) report estimated that over 83% of the global population lacks access to adequate pain management, with some regions having no pain management resources at all. Inaccurate pain assessment and subsequent inadequate pain treatment can lead to severe outcomes for critically ill patients. Proper pain assessment is crucial for providing quality care, and using validated pain measurement tools can improve the evaluation of multidisciplinary pain management strategies for nonverbal ICU patients [10-14].

Puntillo et al. found that in patients with impaired verbal communication (e.g., mechanically ventilated or recently extubated), the most common physiological indicators of pain were increased heart rate and arterial blood pressure. In our study, facial expression played a significant role in pain rating, aligning with findings from other studies that assess both acute and chronic pain. Move-

ment contributed equally to facial expression in pain rating, and compliance with mechanical ventilation also impacted pain assessment. However, factors unrelated to pain, such as hypoxemia, bronchospasm, and mucous plugging, can affect this subscale [15].

The CPOT demonstrated good feasibility, with an average assessment time of only 4 minutes, making it suitable for routine clinical use. Puntillo KA et al. observed pain-related behaviours during various procedures, identifying specific behaviours such as grimacing, rigidity, and moaning. While self-reporting remains the gold standard for pain assessment, the CPOT's four components facial expressions, body movements, muscle tension, and compliance with the ventilator or vocalization provide a comprehensive approach for intubated and extubated patients. Each component is rated on a (0–2) scale, with a total score ranging from 0 to 8 [16].

The purpose of this study was to evaluate the impact of implementing the CPOT on pain assessment and patient outcomes, including ICU length of stay and morbidity/mortality rates. As hypothesized, there was a significant increase in pain assessment frequency and a tendency towards improved pain management practices after CPOT implementation. This indicated a shorter ICU stay for patients assessed for pain, our study also found that the mean ICU stay was shorter in cases (9.67 days ± 4.36 days) compared to controls (10.69 days ± 4.80 days) [3].

Our study also observed significant increases in physiological indicators during painful procedures, which aligns with clinical observations associating pain with variations in physiological variables. However, physiological indicators lack specificity in the ICU and can be influenced by medications and pathological conditions, leading to no significant correlation between CPOT values and physiological variables in our study.

Additionally, the correlation between the CPOT and Ramsay Sedation Scale was negative and significant, suggesting that higher sedation levels are associated with reduced expression of painful behaviours. Although the CPOT total score was higher during procedures, this difference was not statistically significant. Notably, the mortality rate was lower in the cases (7 out of 48) compared to the controls (17 out of 48), highlighting the potential benefits of using the CPOT in pain management for critically ill patients [17].

## LIMITATIONS OF STUDY

The validation process has not been explained, namely, the criterion validity (validity of the CPOT in comparison with another validated pain scale). Secondly, change in patient care management and support for the CPOT quality initiative may have compromised the external validity of the project. Thirdly, we could have compared the CPOT to a subjective rating of the level of pain using a visual analogue scale.

## CONCLUSIONS

Based on study findings, it is evidenced that the CPOT has good psychometric properties and can be adopted to standardize pain assessment for ventilated patients who are unable to self-report pain. And also, application of CPOT decreased the patient's stay in the intensive care unit and decreased amount of morbidity/mortality. We recommend similar studies testing the utilization and effectiveness of the CPOT in larger samples and in different critical care environments to further assess the relationships between the use of behavioural pain scales and clinical outcomes.

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