

Procalcitonin: changes and outcomes in pediatric sepsis at Chiang Mai University Hospital

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Objectives Among a large array of laboratory tests for identifying sepsis, procalcitonin (PCT) has emerged as the leading biomarker for indicating sepsis accurately and in a timely manner. Our study aimed to characterize the change in PCT levels in pediatric sepsis cases and to determine the association with mortality, length of stay (LOS) in the pediatric ICU, and PRISM III score.

Methods In this prospective observational study, pediatric patients diagnosed with sepsis and septic shock were enrolled. Demographic information, laboratory data and PCT levels at 0-24 hours and at 72-96 hours after admission were collected. PRISM III scores were assessed and 28-day mortality and LOS were recorded.

Results Sepsis severity in the 58 children enrolled (median age 14.5 months, range 1-180 months) was classified as both sepsis (n=19, 32.7%) and septic shock (n=39, 67.2%). Respiratory tract infection was the most common cause. We found that a PCT level of 1.38 ng/mL can be used to distinguish between sepsis and septic shock with a sensitivity of 76.9% and a specificity of 68.4%. A reduction in PCT of less than 15% following treatment was associated with a higher mortality rate (OR 70.4, 95% CI, 7.23-685.08; $p < 0.001$), but was not associated with LOS in the pediatric intensive care unit (PICU) or PRISM III score.

Conclusion PCT level can be used to classify sepsis severity. A reduction in PCT level of 15% or more within 72-96 hours after treatment is associated with an improved survival rate, but is not associated with LOS in PICU or with PRISM III score. **Chiang Mai Medical Journal 2019;58(4):223-31.**

Keywords: procalcitonin, sepsis, children, intensive care

Introduction

Sepsis and septic shock are the most significant causes of death and intensive care admissions in the pediatric population worldwide (1). Sepsis and septic shock lead to high morbidity and mortality in children, especially children with comorbidities. Almost half of pediatric sepsis is due to pulmonary infection, the most common cause. The second most common cause is bacteremia (2). Early recognition and intervention together with

close hemodynamic evaluation and monitoring of sepsis patients are crucial factors in effective sepsis management. There are presently a number of blood markers for sepsis which can assist clinicians in monitoring patients apart from clinical signs and symptoms (3).

Ideal biomarkers for sepsis should be both easy to use and readily available. Laboratory tests should have high sensitivity and specificity;



moreover, the tests should rapidly demonstrate increases and decreases in levels of sepsis in response to appropriate treatment as well as changes in clinical severity. C-reactive protein (CRP), erythrocyte sedimentation rates (ESR) and white cell counts are widely used as biomarkers for sepsis; however, they lack specificity (4,5). New biomarkers such as procalcitonin (PCT), blood lactate, CD64, interleukins 6,8,18 (IL-6, -8, -18), human neutrophil gelatinase and proadrenomedullin may also be used in screening, diagnosis, monitoring of clinical symptoms, identifying risks and developing a prognosis in cases of paediatric sepsis (6, 7).

PCT is a precursor of calcitonin which is produced in the thyroid to regulate serum calcium concentrations (6-9). An advantage of PCT as a sepsis biomarker is that it is more specific for bacterial infection than other markers. PCT level rises to a peak in 24-36 hours after an inflammatory trigger and returns to normal by the third day (8,10). However, PCT is more expensive and also has greater variance in cut-off value, sensitivity and specificity than other sepsis biomarkers. Many sepsis studies have demonstrated that PCT levels can identify bacterial infection and may be indicators for the use of antibiotics (11-16). In addition, serial PCT measurements have been shown to be related to disease severity, multiple organ dysfunction and mortality (13-17). For those reasons, PCT levels is potentially useful for diagnosis of sepsis and for use as prognostic biomarker for sepsis; however, there currently are only a limited number of studies of PCT in pediatric sepsis.

Objectives

The first objective of our study was to evaluate the relationship between PCT levels in pediatric patients and the incidence of sepsis and septic shock. The second objective was to determine the association between changes in PCT levels and the 28-day mortality rate, PRISM III score and length of stay (LOS) in the pediatric intensive care unit (PICU).

Methods

Patient population

One-month- to 15-year-old pediatric patients in PICU and wards at Chiang Mai University Hospital who were diagnosed with sepsis and septic shock from August 2017 to August 2018 according to the Surviving Sepsis Campaign: International Guidelines for Management of Severe Sepsis and Septic Shock 2012 (18) were recruited. Children who fulfilled the inclusion criteria were enrolled and were categorized into two groups: sepsis and septic shock. Patients who died within 24 hours after diagnosis and who had conditions that could interfere with the PCT level, i.e., creating either false positive (severe heart failure, severe trauma, burn) or false negative (chronic steroid use), results were excluded. The full-board review study was approved by the Research Ethics Committee, Faculty of Medicine, Chiang Mai University. Informed consent was obtained from patients and parents. Enrollment for patient management in the study was based on the decision of ICU physicians following recommendations in the Surviving Sepsis Campaign Guidelines. A total of sixty-five patients were enrolled of whom seven were later excluded. All 58 patients included in the study were completely followed up for 28 days.

Study design

This single-center, prospective observational study was conducted in a tertiary care hospital. Patient data, including age, sex, underlying diseases, source of infection, mechanical ventilator use, vasoactive drug use, central venous catheter use, results of laboratory tests (complete blood count biochemistry, coagulation, liver function test, arterial blood gas), PRISM III score (19), LOS in PICU, mortality, PCT levels at 0-24 hours and at 72-96 hours after admission were recorded. Patients were followed for sepsis outcome through the 28th day of hospitalization or until the patient was discharged from the hospital.

Measurement of biomarkers

PCT levels were measured at 0-24 hours and at 72-96 hours after diagnosis with either sepsis

or septic shock. Five mL of venous blood was collected in a clotted blood tube and the PCT levels were analyzed immediately using a commercially available Electrochemiluminescence Immunoassay (ECLIA) method (BRAHMS PCT kit, Roche, Henningsdorf, Germany). Serum PCT samples were divided and stored at -80 °C for further analysis. The range of PCT measurements was 0.02 to 100 ng/mL. No values greater than 100 ng/mL were detected.

Statistical analysis

Data analysis was carried out using IBM SPSS 23.0. The demographic data were evaluated using descriptive statistics. Normally distributed continuous variables were compared using Student's t-test and skewed continuous variables were compared using the Mann-Whitney U test. Categorical data were evaluated by Chi-square test or Fisher's exact test. A *p*-value less than 0.05 indicated statistical significance. The diagnostic ability of the PCT levels was determined using the receiver operating characteristics (ROC) curve. Correla-

tions between prognostic factors and 28-day mortality rate, PRISM III score and LOS in PICU were calculated by univariate analysis.

Results

Demographic data

Sixty-five pediatric patients with sepsis and septic shock were admitted between August 1, 2017 and August 31, 2018. Seven of those patients were not recruited into this study due to exclusion criteria. Comparison of clinical and laboratory data between the sepsis group and the septic shock group are shown in Table 1. The median age was 14.5 months, and half the pediatric patients were male (50%). Almost half (27 patients, 46.5%) had underlying diseases. Among the underlying diseases or multiple anomalies identified were hematologic malignancy (7 patients, 25.9%), solid tumor (6 patients, 22.2%), metabolic disorders such as methylmalonic acidemia, propionic acidemia and maple syrup urine disease (5 patients, 18.5%). In addition, short bowel syndrome occurred in 2 patients (7.4%), renal

Table 1. Baseline and demographic data

Parameters	Sepsis severity		Overall	<i>p</i> -value
	Sepsis (n=19)	Septic shock (n=39)		
Age (months)	10.5 (4.5, 20.5) ^a	18 (5, 78) ^a	14.5 (4.7, 50) ^a	0.554
Sex (male: female)	1.1: 1	0.9: 1	1: 1	0.5
Mechanical ventilator use	9 (47.3%)	33 (84.6%)	42 (72.4%)	0.005
Bleeding episode	4 (21%)	10 (25.6%)	14 (24.1%)	1
Transfusion requirement	5 (26.3%)	26 (66.6%)	31 (53.4%)	0.005
Vasoactive drug use	7 (36.8%)	31 (79.4%)	38 (65.5%)	0.003
Central venous catheter use	10 (52.6%)	30 (76.9%)	40 (68.9%)	0.076
LOS in PICU	4 (4, 9) ^a	7 (5, 12) ^a	7.4 (4, 11) ^a	0.641
Modified PRISM III Score	5±5.23	8±5.77	7±5.98	0.093
Mortality	1 (5.2%)	8 (20.5%)	9 (15.5%)	0.247
PCT at 0-24 hr (ng/mL)	0.62 (0.27, 7.63) ^a	6.64 (1.69, 22.62) ^a	4.48 (0.59, 17.08) ^a	0.013
PCT at 72-96 hr (ng/mL)	0.17 (0.04, 1.43) ^a	2.41 (0.77, 7.41) ^a	1.26 (0.18, 6.34) ^a	0.002
Hemoglobin (g/dL)	10.45±1.94	10.44±2.13	10.44±2.05	0.394
ANC (cell/mm ³)	8,373±4,699	8,004±6,647	8,123±6,048	0.438
Platelet (cell/mm ³)	328,444±102,141	287,701±209,287	300,797±181,823	0.372
Albumin (g/dL)	3.72±0.975	3.26±0.80	3.4±1.81	0.248
Creatinine (mg/dL)	0.25 (0.17, 0.34) ^a	0.48 (0.25, 0.81) ^a	0.28 (0.23, 0.59) ^a	0.722

^aMedian (interquartile range), LOS; length of stay, PICU; pediatric intensive care unit, PCT; procalcitonin, ANC; absolute neutrophil count

anomalies in 2 patients (7.4%). Other conditions (primary immune deficiency, thalassemia, bronchopulmonary dysplasia, Down syndrome and congenital hypotonia) were found in 5 patients (18.5%). The most common primary source of sepsis was pulmonary infection, found in 31 patients (53.5%). Other sites of infection were the bloodstream, confirmed by culture in 13 patients (22.4%), gastrointestinal infection in 5 patients (8.6%) and others (skin infection, central nervous system infection, nosocomial infection) in 9 patients (15.5%). Overall, the mortality incidence was 15.5 % (n = 9). The median LOS in PICU was 7.4 days (range 4-11 days). The mean PRISM III score was 7 ± 5.98 . The median PCT level at 0-24 and 72-96 hours in the entire cohort was 4.48 ng/mL (0.59, 17.08) and 1.26 ng/mL (0.18, 6.34), respectively (Table 1).

Nineteen patients (32.8%) were classified with sepsis and 39 patients (67.2%) were classified with septic shock. Patients with septic shock had more mechanical ventilator use [9 patients (47.3%) vs 33 patients (84.6%), $p=0.005$], transfusion requirements [5 (26.3%) vs 26 (66.6%), $p=0.005$] and vasoactive drug use [7 (36.8%) vs 31 (79.4%), $p=0.003$] than the sepsis group. Moreover, the septic shock group had higher PCT values than the sepsis group at 0-24 hours and at 72-96 hours [0.62 ng/mL (0.27, 7.63) vs 6.64 ng/mL (1.69, 22.62), $p=0.013$] and [0.17 ng/mL (0.04, 1.43) vs 2.41 ng/mL (0.77, 7.41), $p=0.002$], respectively. The sensitivity and specificity of PCT level at 0-24 hours was used to categorize sepsis severity as either sepsis or septic shock using the ROC curve. The PCT level of 1.38 ng/mL had the best sensitivity (76.9%) and specificity (68.4%) for discriminating between sepsis and septic shock (Figure 1).

Clinical parameters associated with LOS

LOS in PICU was classified as less than 7 days, 7-14 days and more than 14 days. More than half the patients were admitted to the PICU for less than 7 days. Only the use of a mechanical ventilator showed a significant difference ($p=0.005$) among the different LOS groups. Decrease of PCT, PRISM III score ≥ 8 , hemoglobin <10 g/dL

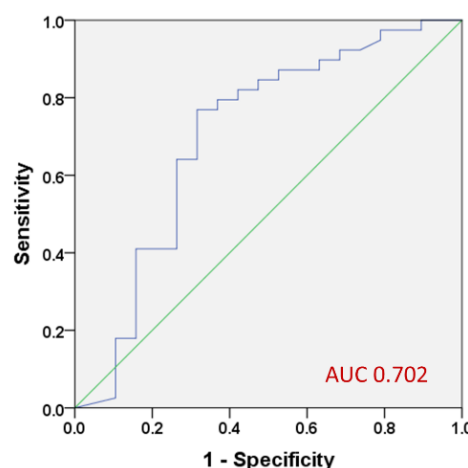


Figure 1. ROC curve demonstrating the sensitivity and specificity of PCT levels at 0-24 hours for identifying sepsis severity

and absolute neutrophil count (ANC) $<1,500$ cell/ mm^2 were not found to be associated with LOS.

Clinical parameters associated with a PRISM III Score

PRISM III scores were classified into two groups, scores <8 and scores ≥ 8 . Among the parameters measured, the presence of ANC $<1,500$ cell/ mm^2 was substantially predominant in the PRISM III score ≥ 8 group with a statistical significance of 0.016 (Table 2).

Clinical parameters associated with mortality

Percentage decrease of PCT levels from the PCT levels at 0-24 hours and 72-96 hours was calculated using the following formula:

The percentage of decreasing PCT =

$$\frac{\text{PCT level}_{0-24 \text{ hour}} - \text{PCT level}_{72-96 \text{ hour}}}{\text{PCT level}_{0-24 \text{ hour}}} \times 100\%$$

Percentage decrements of PCT levels of 15, 30, 60 and 90 showed a sensitivity of 78.1%, 75%, 59.4% and 12.5% and a specificity of 23.1%, 30.8%, 61.5% and 80.8%, respectively. We decided to use the 15% decrement of PCT for screening the mortality of pediatric sepsis and septic shock (Figure 2). Almost all patients who had a decrease in PCT levels of 15% or more were in the survival

Table 2. Clinical parameters associated with modified PRISM III Score

Parameters	Modified PRISM III Score		<i>p</i> -value
	<8 (n=33)	≥8 (n=25)	
Reduction of PCT Level < 15%	5 (15.2%)	8 (32%)	0.203
Hemoglobin <10 g/dL	12 (36.4%)	13 (52%)	0.289
ANC <1,500 cell/mm ²	1 (3%)	7 (28%)	0.016
Use of mechanical ventilator	21 (63.6%)	21 (84%)	0.138

PCT; procalcitonin, ANC; absolute neutrophil count

Table 3. Clinical parameters associated with mortality

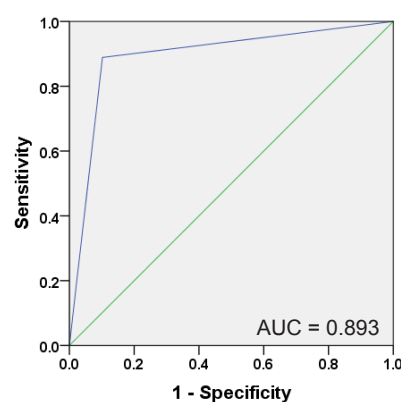
Parameters	Outcome		Unadjusted odds ratio (95% CI)	<i>p</i> -value
	Survivor (n=49)	Non-survivors (n=9)		
Reduction of PCT Level <15%	5 (10.2%)	8 (88.9%)	70.4 (7.23-685.08)	< 0.001
Modified PRISM III Score ≥8	17 (34.7%)	8 (88.9%)	15.1 (1.73-130.64)	0.014
Hemoglobin <10 g/dL	21 (42.9%)	4 (44.4%)	-	1.000
ANC <1,500 cell/mm ²	5 (10.2%)	3 (33.3%)	-	0.099
Use of mechanical ventilator	33 (67.3%)	9 (100%)	-	0.051

PCT; procalcitonin, ANC; absolute neutrophil count

group. All patients who died used mechanical ventilators while two-thirds of the survivors used them (Table 3). The presence of anemia, low ANC and the use of a mechanical ventilator were not associated with increased mortality. A reduction of PCT level <15% [5 (10.2%) vs 8 (88.9%)] and PRISM III score ≥8 [17 (34.7%) vs 8 (88.9%)] was statistically significantly associated with mortality rate. Univariate analysis indicated that the pediatric patients with a reduction of PCT level <15% had a mortality rate 70.4 times that of the other group (OR 70.4, 95% CI, 7.2-685; $p < 0.001$). The patients with a high PRISM III score (≥8) had a 15.1 times higher mortality rate (OR 15.1, 95% CI, 1.73-130.64; $p = 0.014$).

Discussion

Sepsis and septic shock, triggered by infection, inflammatory process and immune response, are life-threatening conditions in pediatric patients. In addition to clinical diagnosis, biomarkers have an important role in the diagnosis and monitor-

**Figure 2.** Relationship between the percentage of reduction of PCT Level < 15% and mortality rate from ROC

ing of sepsis and septic shock. An ideal biomarker should be inexpensive, readily available and have high diagnostic accuracy. Currently, there are a number of biomarkers for sepsis; however, they each have limitations for use in screening, diagnosis, monitoring and prognosis (4,6,11).

PCT, a 116-amino acid prohormone, is generated by thyroid C-cells (parafollicular cells) and by

neuroendocrine cells in the lungs and intestines. PCT is controlled by the calcitonin gene related peptide 1 (*CALC-1*) gene (4,9,11,20). During sepsis, extra-thyroid tissue and other cells (liver, pancreas, kidneys, leukocytes and adipose tissue) show increased *CALC-1* gene expression, and, as a result, serum PCT level elevation (20). Several studies have shown that PCT can be used for distinguishing between bacterial and other infections (21-24). Thus, PCT can be utilized as a diagnostic and prognostic marker for sepsis (11). Although PCT exhibits variation in sensitivity and specificity, it can detect sepsis earlier and more accurately than CRP (6,8,10). Studies have demonstrated this greater accuracy (13,25). In addition, several studies have suggested that serial measurement of PCT may be a good prognostic marker for identifying the severity of sepsis, as well as the risk of multi-organ failure and mortality (13-15, 26-28).

This study measured PCT levels in pediatric patients with sepsis and septic shock and demonstrated the relationship between PCT level and disease severity. The study also described the association between change in PCT level and 28-days mortality rate, PRISM III score and LOS in PICU. First, we found that PCT levels were statistically different between the pediatric sepsis and the septic shock groups. We calculated the optimal level of PCT which can differentiate sepsis and septic shock using the ROC curve. The children with septic shock had higher PCT values at 0-24 hours which was related to the severity of the disease. Moreover, our study found that a PCT level of 1.38 ng/mL had the best sensitivity (76.9%) and specificity (68.4%) to discriminate between sepsis and septic shock. Rey C, et al. studied PCT, CRP and leukocyte counts in a PICU and found that PCT was better than CRP in separating 6 classes of pediatric patients (negative, systemic inflammatory response syndrome (SIRS), localized infection, sepsis, severe sepsis, and septic shock patients). Their data showed that PCT levels could be used to classify disease severity (AUC = 0.91, 95% CI, 0.882-0.943) (25). That indicates PCT might be a useful marker for

classifying the severity of sepsis.

Second, this study included parameters associated with the 28-day mortality rate, PRISM III score and LOS in the PICU. Use of mechanical ventilators was associated with longer LOS, while lower ANC values were associated with higher PRISM III score. We monitored the decrement of PCT to evaluate the use of PCT both as a prognostic biomarker for mortality and as a monitoring biomarker. We found that good outcomes in cases of pediatric sepsis and septic shock were related to decreasing PCT levels. Reduction of PCT level $\geq 15\%$ could be a screening biomarker for estimation of the chance of survival of pediatric sepsis and septic shock with a sensitivity of 78.1% and a specificity of 23.1% as pediatric patients with a reduction of PCT level $\geq 15\%$ had a better prognosis than the others. The reduction of PCT level $\geq 15\%$ could be a key parameter for clinicians to use in planning further management and intervention. Hatherill M, et al. studied PCT levels in 75 children with sepsis and concluded that higher PCT levels at admission was related to mortality and organ failure (17). Poddar B, et al., who studied the change of PCT levels in 25 pediatric patients with sepsis, reported that the children with a greater reduction of PCT level (>4 ng/mL or $>50\%$ from baseline) had a higher rate of survival (27). Pieralli F, et al., who studied PCT levels in 144 adults, suggested that PCT scores were a tool for predicting mortality in cases with a reduction of PCT level at 0-72 hours of less than 15% (AUC 0.75; 95%CI: 0.67-0.82) (HR: 3.9, 95% CI: 1.6-9.5; $p < 0.0001$) and a reduction of PCT level at 24-72 hours of less than 20% (AUC 0.83; 95%CI: 0.74-0.92) (HR: 3.1, 95% CI: 1.2-7.9; $p < 0.001$) (29). However, Zurek J, et al., who studied PCT levels in 62 children admitted to PICU, found that PCT levels could not be used to classify the severity of sepsis except in cases where the patient developed organ failure (26).

Limitations of this study include the small sample size and the variability in the length of time from admission to measurement of PCT. Additionally, PCT levels greater than 100 ng/dL were recorded as 100 ng/dL, so the percentage

decrease of PCT may have been underestimated in some cases.

Conclusions

PCT levels can be used to classify the severity of sepsis. A reduction of PCT level of 15% or more after treatment can be a good prognostic parameter in evaluating pediatric sepsis and septic shock.

Abbreviations

ANC: absolute neutrophil count, CRP: C-reactive protein, dl: deciliters, ECLIA: Electrochemoluminescence Immunoassay, ESR: erythrocyte sedimentation rates, g: grams, IL: interleukins, LOS: length of stay, ml: milliliter, mm³: cubic millimeter, ng: nanograms, PCT: procalcitonin, PICU: pediatric intensive care unit, Pediatric Risk of Mortality score: PRISM III score ROC: receiver operating characteristic, SIR: systemic inflammatory response syndrome

Authors' contributions

KS designed the project, analysed and interpreted the data, wrote and submitted the manuscript; SC collected the patient data; SR revised the manuscript.

All authors reviewed the manuscript and approved the final version to be published.

Ethics approval and consent to participate

The study was approved by Research Ethics Committee, Faculty of Medicine, Chiang Mai University and informed consent was obtained from each patient and their family.

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None

Competing interests

The authors declare that they have no competing interests.

Conflict of interest

No conflicts of interest.

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การเปลี่ยนแปลงของระดับโปรแคลซิโตนินและพยากรณ์โรคในผู้ป่วยเด็กที่มีภาวะติดเชื้อในกระแสเลือดโรงพยาบาลมหาวิทยาลัยเชียงใหม่

สุติดา ชาญยุทธนา, กนกกาญจน์ สันกลกิจ และ สนิท เรืองรองรัตน์
ภาควิชากุมารเวชศาสตร์ คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

วัตถุประสงค์ โปรแคลซิโตนินเป็นหนึ่งตัวชี้วัดของการส่งตรวจทางห้องปฏิบัติการซึ่งใช้ในการวินิจฉัยภาวะติดเชื้อในกระแสเลือดอย่างถูกต้องและรวดเร็ว วัตถุประสงค์ของการศึกษานี้เพื่อประเมินการเปลี่ยนแปลงของระดับโปรแคลซิโตนินในภาวะติดเชื้อในกระแสเลือดในผู้ป่วยเด็กและหาความสัมพันธ์ระหว่างการเปลี่ยนแปลงของระดับโปรแคลซิโตนินกับอัตราการเสียชีวิต ระยะเวลาการนอนในหอผู้ป่วยวิกฤต และคะแนน PRISM III

วิธีการ ศึกษาแบบไปข้างหน้า ผู้ป่วยเด็กที่ได้รับการวินิจฉัยภาวะติดเชื้อในกระแสเลือดจะได้เข้าร่วมการวิจัย ข้อมูลที่รวบรวมประกอบด้วยลักษณะทั่วไป ผลการตรวจทางห้องปฏิบัติการ ระดับโปรแคลซิโตนินที่ 0-24 ชั่วโมงและ 72-96 ชั่วโมง คะแนน PRISM III อัตราการเสียชีวิตและระยะเวลาการนอนในหอผู้ป่วยวิกฤต

ผลการศึกษา มีผู้ป่วยเด็กเข้าร่วมวิจัยจำนวน 58 ราย (อายุมาตรฐาน 14.5 เดือน; ระหว่าง 1-180 เดือน) ความรุนแรงของภาวะติดเชื้อในกระแสเลือดถูกแบ่งออกเป็น ภาวะติดเชื้อในกระแสเลือด ($n=19$, ร้อยละ 32.7) และภาวะช็อกจากภาวะติดเชื้อในกระแสเลือด ($n=39$, ร้อยละ 67.2) ตำแหน่งการติดเชื้อที่สำคัญที่พบบ่อยที่สุด คือ ภาวะติดเชื้อจากทางเดินหายใจ จากการศึกษาพบว่าระดับโปรแคลซิโตนินที่ 1.38 นาโนกรัม/มิลลิลิตร สามารถจำแนกภาวะติดเชื้อในกระแสเลือดและภาวะช็อกจากภาวะติดเชื้อในกระแสเลือดได้โดยมีความไวร้อยละ 76.9 และความจำเพาะร้อยละ 68.4 นอกจากนี้พบว่าผู้ป่วยที่มีระดับการลดลงของโปรแคลซิโตนินน้อยกว่าร้อยละ 15 หลังการรักษาจะมีอัตราการเสียชีวิตมากกว่า 70.4 เท่า (OR 70.4, 95% CI, 7.23-685.08; $p<0.001$) แต่อย่างไรก็ตามพบว่าไม่มีความสัมพันธ์ระหว่างการเปลี่ยนแปลงของโปรแคลซิโตนินกับคะแนน PRISM III และระยะเวลาการนอนในหอผู้ป่วยวิกฤตอย่างมีนัยสำคัญทางสถิติ

สรุป โปรแคลซิโตนินเป็นตัวชี้วัดที่สามารถจำแนกระดับความรุนแรงของภาวะติดเชื้อในกระแสเลือดในผู้ป่วยเด็กได้ การลดลงของโปรแคลซิโตนินมากกว่าร้อยละ 15 หลังการรักษาจะสัมพันธ์กับอัตราการรอดชีวิต แต่อย่างไรก็ตามไม่มีความสัมพันธ์กับคะแนน PRISM III และระยะเวลาการนอนในหอผู้ป่วยวิกฤต **เชียงใหม่เวชสาร 2562; 58(4):223-31.**

คำสำคัญ: โปรแคลซิโตนิน ภาวะติดเชื้อในกระแสเลือด เด็ก การรักษาพยาบาลผู้ป่วยหนัก

