Serum Procalcitonin in Diagnosis of Bacteremia

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Objective: *To (a) determine the diagnostic value of procalcitonin (PCT) in differentiating sepsis with or without bacteremia, (b) evaluate the correlation of PCT levels to severity of sepsis, (c) establish the prognostic value in predicting the outcome of sepsis and (d) evaluate the correlation among different assays.*
Material and Method: *A prospective study was carried out from August through November 2007. Blood for PCT levels and culture were drawn simultaneously.*
Results: *Fifty-six patients with clinical suspicious of sepsis were enrolled in the study; bacteremia (n = 30) and non-bacteremia (n = 26). There were good correlations between the PCT levels measured by three assays ($p < 0.001$). At the threshold of 0.5 ng/mL, PCT had > 90% sensitivity for diagnosis of bacteremia. Of the bacteremic group, median PCT levels measured by Kryptor and VIDAS assays were 12.4 and 16.6 ng/mL respectively. In the non-bacteremic group, median PCT levels measured by Kryptor and VIDAS were 4.2 and 4.9 ng/mL respectively. PCT levels were significantly higher in the bacteremic group ($p = 0.04$). The optimum thresholds to discriminate between these two groups were found to be 5, 6.5 and 2 ng/mL for Kryptor, VIDAS and PCT-Q, respectively. In addition, correlations of PCT and increasing values of the APACHE II score were observed. PCT levels in the severe sepsis and MOD group were also found to be significantly higher.*
Conclusion: *PCT was highly sensitive in detecting bacteremia, although not very accurate in differentiating bacteremic from non-bacteremic SIRS in adult patients.*

Keywords: *Bacteremia, Calcitonin, Procalcitonin, Protein precursors, Sepsis, Systemic inflammatory response syndrome*

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Bacteremia may constitute a life-threatening condition that requires prompt administration of intravenous antibiotics. The critically ill patient frequently presents similar clinical pictures in infection, organ dysfunction, and in the various severities of a systemic inflammatory response syndrome (SIRS). Also, differences in body temperature, heart rate, white blood cell count, and respiratory rate are often small. As a consequence, diagnosis of sepsis and infection can be difficult: positive bacteriological samples may be late or absent, the clinical interpretation of local colonization may be ambiguous, and traditional markers of infection such as BT and WBC count may be unspecific. Moreover, only 5-10% of blood cultures performed in hospitals grows microorganisms[1]. A rapid and reliable test to rule out bacteremia would thus help in decision making and could have an impact both on the length of stay and the costs.

In 1993, Assicot et al[2] reported that elevated levels of serum procalcitonin (PCT) were closely related to the onset of bacterial infection and seemingly correlated to severity of infection. Several clinical studies have detected a high PCT level in patients with evidence of systemic bacterial infection, whereas relatively low PCT levels, on the other hand, occur in patients with only localized bacterial infection or viral infection, as reviewed by Simon et al[3]. Bacterial endotoxins are a major stimulus for PCT induction[4]. PCT is a marker that correlates very well with both

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mortality and severity of infection[5-7]. PCT can also help to monitor the progress of focus control and the efficacy of antibiotic treatment[8].

In several studies investigating diagnostic parameters of various biomarkers in diagnosis of sepsis, PCT proved to be superior to C-Reactive Protein (CRP), Interleukin-6 (IL-6), Interleukin-8 (IL-8), Erythrocyte sedimentation rate (ESR) and tumor necrosis factor-a. In addition, PCT in conjunction with other laboratory markers were discriminatory for identifying severe sepsis and sepsis[9,10]. In the recent study of community-acquired bacteremia, PCT had a high negative predictive value for bacteremia[11]. However, several investigators found that PCT was not a sensitive marker of gram positive bacteremia especially Coagulase-negative *Staphylococcus*[12]. A number of quantitative and qualitative (semi-quantitative) assays for PCT are available from BRAHMS (Germany). The following commercial PCT assays are recently available in Thailand.

Quantitative test

- Time-resolved amplified cryptate emission (TRACE) technology (BRAHMS PCT Kryptor®)
- Enzyme-linked fluorescent assay (ELFA, VIDAS BRAHMS PCT)

Semiquantitative test

- BRAMHS PCT®-Q. The PCT-Q is a test strip utilizing immunochromatographic technology.

Study has shown more than 95% concordance among Kryptor, VIDAS and PCT LIA assays (www.biomerieux-diagnostics.com).

The aims of the present study were to (a) determine the diagnostic value of PCT in differentiating sepsis with or without bacteremia, (b) evaluate the correlation of PCT levels to the severity of sepsis, (c) establish its prognostic value in predicting the outcome of sepsis (recovery versus death), (d) evaluate the correlation between three different assays, and (e) determine the differences between PCT levels in gram-positive versus gram-negative bacteremia.

Material and Method

The study was approved by the Institutional Ethics Committees of the Faculty of Medicine Siriraj Hospital. Written informed consent was obtained from the patients or their relatives to permit blood sampling to measure the levels of PCT. Serum specimens were collected prospectively from August through November 2007. Inclusion criteria were adult patients who were hospitalized in Siriraj hospital with clinical suspicions of sepsis, either community or hospital acquired. The diagnosis and grading of sepsis were performed according to the SIRS/sepsis criteria that were accepted by the American College of Chest Physicians/Society of Critical Care Medicine (ACCP/SCCM) consensus conference[13]. The definition of sepsis was based on the presence of at least two of the following criteria: fever or hypothermia (> 38°C or < 36°C); tachycardia (> 90 beats/min); tachypnea (> 20 breaths/min) or PaCO2 < 32 mmHg; and leukocytosis (> 12,000/μl), leukopenia (< 4,000/μl), or more than 10% immature forms in addition to foci of infection. Additional requirements for severe sepsis were at least one of the following: hypotension (systolic blood pressure < 90 mmHg or a drop in systolic blood pressure of > 40 mmHg corrected by fluid replacement for more than 1h), arterial hypoxemia (PaO2 < 75 mmHg without evidence of primary lung disease), metabolic acidosis (pH ≤ 7.3 or base deficit ≥ 5 mEq/l), oliguria (urine output ≤ 30 ml/h despite adequate fluid replacement for at least 2 h); acute alteration of mental status; and recent coagulation abnormality (prothrombin time or activated partial thromboplastin time ≥ 1.2 times the upper normal values, D-dimers ≥ 500, platelets < 100,000/ml). Septic shock was defined as severe hypotension that lasted more than 1 h despite adequate fluid replacement; in addition to sepsis that met the definitions for severe sepsis. Sepsis with multiple organ dysfunction syndromes (MODS) was defined as severe sepsis with two or more organ dysfunctions. The patients were divided into two groups by the results of blood culture. The bacteremic group is comprised of consecutive adult patients with at least one blood culture positive for a usual pathogen or at least two positives for a possible contaminant (e.g. coagulase-negative *Staphylococcus*).

Laboratory measurements

The blood samples for PCT and culture were drawn at the same time that other tests ordered by the treating physician were performed. Blood was collected in aerobic culture bottles and incubated for a maximum of 7 days in an automatic analyzer (Bact T/Alert). At inclusion, specimens for microbiological investigation were collected depending on the clinical infection. The specimens were processed by standardized procedures. Samples for PCT were centrifuged to separate the serum, which were frozen at -20°C for further analysis. All serum samples were analyzed

using three commercially available PCT assays in Thailand including Time-resolved amplified cryptate emission technology (BRAHMS PCT Kryptor), Enzyme-linked fluorescent assay (VIDAS® BRAHMS PCT) and Immunochromatographic test (BRAHMS PCT-Q). The measuring principles were described elsewhere (www.procalcitonin.com). VIDAS BRAHMS® and BRAMHS PCT®-Q assays were processed at Siriraj hospital while for Kryptor® PCT analysis assays were transported to Ramathibodi hospital.

The lower detection limit of quantitative assay (VIDAS BRAHMS and BRAMHS PCT®-Q) was 0.06 ng/mL. The upper detection limit of VIDAS was 200 ng/mL. In contrast, there was no upper detection limit for Kryptor for which serum could be further diluted to measure the higher level. A colorimetric, "quick" bedside test (BRAMHS PCT®-Q) has the advantage of rapid determination of circulating PCT levels in 30 minutes. Unfortunately, the assay is only semi-quantitative and with a sensitivity of 0.5 ng/ml. PCT concentrations are reported as, < 0.5, ≥ 0.5, ≥ 2 or ≥ 10 ng/ml.

PCT serum levels were measured in the saved sera using 3 different assays (VIDAS BRAHMS®, BRAMHS PCT®-Q and Kryptor® PCT). Testing was performed in a blinded fashion, without knowing the results of other microbiological investigations. Demographic and clinical data were collected by chart review and/or interviews with the attending physicians. They included the age, gender, date of admission, date and hour of blood drawing, clinical diagnosis of infection, causative organism, previous administration of antibiotics, previous surgical history within 2 weeks, and Acute Physiology and Chronic Health Evaluation (APACHE) II score. The final determination of the patient's status was done retrospectively, without knowledge of plasma PCT levels, on the basis of the complete patient charts. We considered only mortality presumably related to the infections.

Statistical analysis

Statistical analysis was performed by using SPSS 13.0 version for Windows (SPSS, Chicago, IL, USA). Continuous variables were analyzed on the basis of mean, standard deviation, and median values. Fisher's exact test was used for the comparison of the distributions of categorical variables between groups. The Mann-Whitney U test was used for the comparison of the distributions of continuous variables between groups as nonparametric tests. The ability of PCT to predict sepsis with bacteremia was evaluated by performing receiver operating characteristic analyses to compare bacteremic versus non-bacteremic patients. Furthermore, receiver-operating characteristic curves (ROC) were made, plotting sensitivity against 1-specificity at various cutoff points, after logarithmic transformation of the procalcitonin values: the closer the area under the curve (AUC) to 1, the greater the predictive power of a test. The sensitivity, specificity, positive predictive value, and negative predictive value of PCT serum levels to diagnose bacteremia were calculated according to standard formulas. The Spearman rank correlation (rs) was used to express relations. All tests were two-tailed. P-values of less than 0.05 were considered significant.

Results

Fifty-six patients diagnosed with SIRS and suspected of having infectious diseases were enrolled in the study. Characteristics of the patients are presented in Table 1. Patients were categorized into 2 groups based on blood culture results, namely bacteremia (n = 30) and non-bacteremia (n = 26). The following micro-organisms were responsible for bacteremia: *Escherichia coli* (n = 8), *Pseudomonas aeruginosa* (n = 5), *Klebseilla pneumoniae* (n = 3), *Staphylococcus aureus* (n = 3), *Enterococcus faecium* (n = 2), and *Enterobacter cloacae*, *Acinetobacter baumanii*, *Proteus mirabili*s, *Burkholderia pseudomallei*, *Vibrio vulnificus*, *Streptococcus agalactiae*, *Streptococcus pyogenes,* Group D *Streptocuccus*, *Staphylococcus hemolyticus* (1 patient each).

Of the bacteremic group, 26.67% were digestive tract infection, 20% were urinary tract infection, 16.67% were skin and soft tissue, 10% were catheter-related infection and 16.7% were primary bacteremia. Of the non-bacteremic group, the foci of infection were as follows: urinary tract in 8 cases (30.77%), digestive tract in 5 cases (19.23%), skin and soft tissue in 4 cases (15.4%) and lower respiratory tract in 3 cases (11.5%). Six cases (23.1%) in which no foci of infection could be found were accepted as sepsis and were included in the non-bacteremic group because the clinical and laboratory findings strongly suggested sepsis; the clinical picture could not be explained by other reasons.

There were good correlations between the PCT levels measured by Kryptor and VIDAS, Kryptor and PCT-Q, VIDAS and PCT-Q ($p < 0.01$) ($r = 0.99$, $r = 0.94$ and $r = 0.93$, respectively).

Prediction of bacteremia

Using the most commonly described test

Table 1. Characteristics of the study patients

Characteristics	Bacteremic group	Nonbacteremic group
No.	30	26
Age, year (mean ± SD)	51.77 ± 19.36	57.87 ± 17.00
Male/female	14/16	10/16
APACHE II score (mean ± SD)	15.23 ± 7.08	17.69 ± 7.81
Underlying conditions		
Diabetes mellitus	8	10
ESRD	3	1
Cerebrovascular diseases	5	3
Autoimmune diseases	-	1
Hematologic malignancy	3	3
Solid tumor	10	5
Cirrhosis	2	2
HIV/ AIDS	-	3
None	7	2
Community-acquired infections (%)	17 (56.7)	18 (69.2)
In-hospital mortality (%)	14.29	17.86

threshold (0.5 ng/mL) in the diagnosis of bacteremia (10), Kryptor PCT, VIDAS PCT and PCT-Q were shown to have a sensitivity of 93.3%, 96.7% and 93.1, respectively, and specificity of 19.2% for PCT-Q and 23.1% for both VIDAS and Kryptor.

PCT concentrations were similarly elevated in patients with gram-negative and in those with gram-positive infections (Kryptor; p = 0.36, VIDAS; p = 0.42).

Differentiation between bacteremic group versus non-bacteremic group

Of the bacteremic group, median PCT levels measured by Kryptor and VIDAS assays were 12.4 (0.11-1626) and 16.6 (0.13 - 200) ng/mL respectively. In the non-bacteremic group, median PCT levels measured by Kryptor and VIDAS were 4.2 (0.04-184) and 4.9 (0.05-200) ng/mL respectively. When the patients with positive blood cultures and the patients with negative blood cultures were compared, PCT levels measured by both Kryptor and VIDAS assays were significantly higher in the bacteremic group versus the non-bacteremic groups (p were 0.05 and 0.04, respectively).

The PCT levels measured by PCT-Q were categorized into 4 groups according to the test strip (< 0.5, ≥ 0.5, ≥ 2 or ≥ 10 ng/ml). At the cut-off level of 2 ng/ml, PCT-Q was found to be successful in discriminating between bacteremic and non-bacteremic group (p = 0.04). Fig. 1 contains ROC curves showing the sensitivity and specificity of PCT. The values for the diagnostic accuracy PCT measured by different assays are presented in Table 2. The optimum cutoff value and AUC for all assays are shown in Table 3. The AUC were comparable among all three assays (0.65-0.69). The optimum cutoff values to discriminate between bacteremic and non-bacteremic group were found to be 5, 6.5 and 2 ng/mL for Kryptor, VIDAS and PCT-Q, respectively. The sensitivity was 61.6 for both Kryptor and VIDAS assays and 65.4 for PCT-Q.

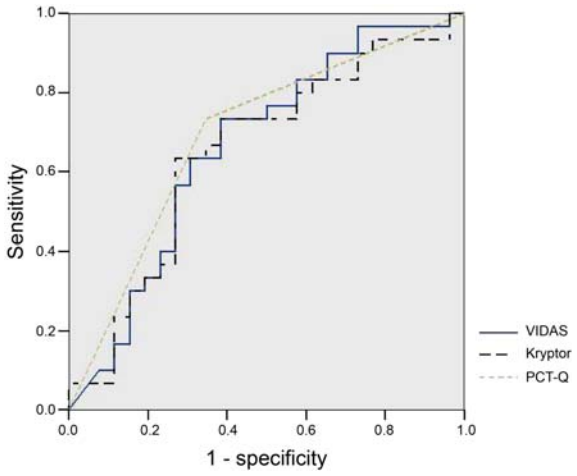

Fig. 1 ROC curves of PCT measured by 3 different assays for prediction of bacteremia in patients with clinical suspicious of sepsis

Table 2. Sensitivity, specificity, positive predictive value (PPV) and negative predictive values (NPV) of serum PCT different cut-off levels measured by Kryptor and VIDAS assays

Method	Cut off value, ng/mL	Sentitivity, %	Specificity, %	PPV, %	NPV, %
Kryptor PCT	0.3	93.3	12.0	56.0	60.0
	0.4	93.3	19.2	57.1	71.4
	0.5	93.3	23.1	57.4	66.7
	0.6	90.0	26.9	58.7	70.0
	0.7	86.7	26.9	57.8	63.6
	0.8	83.3	26.9	56.8	58.3
	4.0	73.3	46.2	61.1	60.0
	4.5	73.3	61.5	68.8	66.7
	5.0	73.3	61.5	67.7	64.0
	5.5	66.7	61.5	66.7	61.5
	6.0	66.7	61.5	66.7	61.5
	6.5	66.7	61.5	66.7	61.5
VIDAS PCT	0.3	96.7	11.5	55.8	75.0
	0.4	96.7	15.4	56.9	80.0
	0.5	96.7	23.1	59.2	85.7
	0.6	96.7	29.2	60.4	87.5
	0.7	96.7	26.9	60.4	87.5
	0.8	93.3	26.9	59.6	77.8
	4.0	80.0	42.3	61.5	64.7
	4.5	76.7	42.3	60.5	61.1
	5.0	73.3	50.0	62.9	61.9
	5.5	73.3	57.7	66.7	65.2
	6.0	73.3	57.7	66.7	65.2
	6.5	73.3	61.5	66.8	66.7
	7.0	73.3	61.5	66.8	66.7
PCT-Q	0.5	93.3	19.2	57.1	71.4
	2.0	73.3	65.4	71.0	68.0
	10.0	73.3	65.4	71.0	68.0

Table 3. The optimum cutoff and AUC value of each assay in predicting of sepsis with bacteremia

Methods	Best cut off value	AUROCCs (mean $\pm$ SE)	p-value
Kryptor	5.0	0.650 ± 0.076	0.054
VIDAS	6.5	0.663 ± 0.037	0.037
PCT-Q	2.0	0.694 ± 0.070	0.010

PCT for predicting severity of sepsis and outcome

When PCT concentration was analyzed according to the various severities of organ dysfunction measured by the APACHE II score, correlations of PCT and increasing values of the APACHE II score were observed ($p < 0.05$, Fig. 2).

According to the diagnostic criteria of the ACCP/SCCM, 28 (50%) cases were stratified as sepsis, 13 (23.2%) as severe sepsis, 10 (17.8%) as septic shock and 5 (8.9) as sepsis with MODS. Thirty-seven (66.1%) patients recovered and nineteen (33.9%) died of infectious-related diseases. Serum concentrations of PCT were statistically different between the septic shock with MODS group and the sepsis group ($p < 0.05$). Sepsis with MODS patients had the highest level of PCT concentrations. PCT levels in the severe sepsis and sepsis with MOD groups were found to be significantly higher. However, no significant differences in the levels of PCT were found between the patients who died and recovered. (Kryptor; $p = 0.12$, VIDAS; $p = 0.16$).

Discussion

In the present study, PCT levels ≥ 0.5 ng/mL exhibit a higher sensitivity in diagnosis of bacteremia along with lower specificity than the previous studies[6,11,14]. A case-control study conducted by

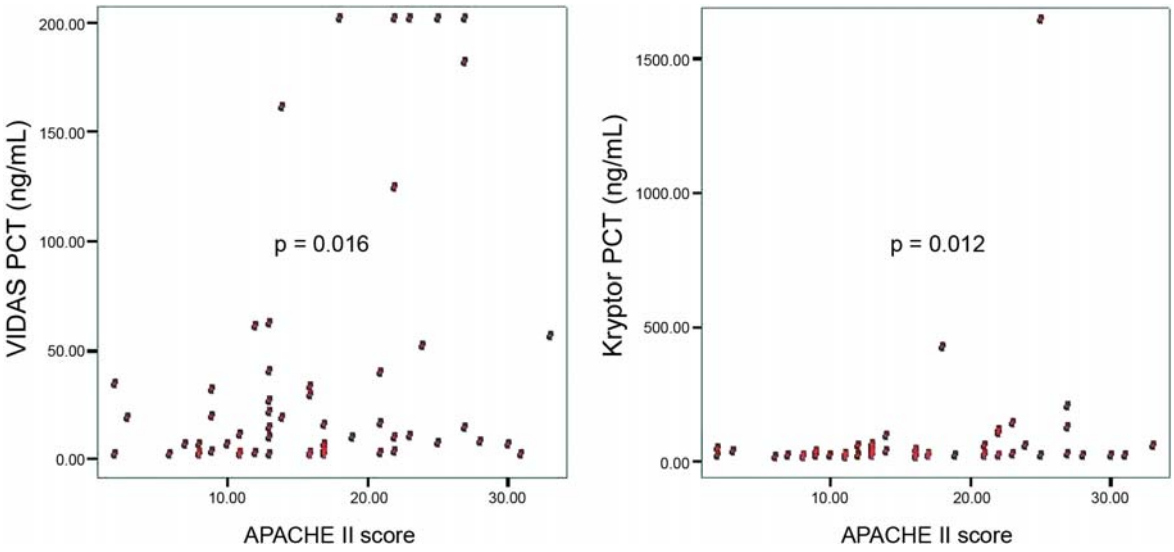

Fig. 2 PCT-APACHE II score correlation in sepsis patients

Liaudat S et al, investigating the usefulness of PCT for the diagnosis of bacteremia, demonstrated that at cut-off values of 0.5 and 0.2 ng/ml, the sensitivity of PCT was 56 and 92%, and the specificity was 83 and 43%, respectively[15]. Bossink and colleagues[16] evaluated performance indices of PCT in a prospective analysis of 300 hospitalized medical patients with fever. By using 0.5 ng/mL as the cut-off value, they found that the sensitivity, negative predictive value, and AUROCC of PCT for the diagnosis of bacteremia were 75%, 90%, and 0.7, respectively. The higher sensitivity that we report may be explained by more severe patients comparing to previous studies. SIRS or clinical sepsis were presented in all the patients in this study, even in the non-bacteremic group, whereas the prevalence was much lower in the previous studies. As a result, PCT levels in the present study were higher according to the severity with relatively low NPV.

The diagnostic utility of PCT in the discrimination of sepsis with bacteremia from sepsis without bacteremia was evaluated, and PCT levels in the bacteremia group were found to be significantly higher by all measurements assays. In this study, median PCT levels measured in bacteremic group by Kryptor and VIDAS assays were 12.4 (0.11-1626) and 16.6 (0.13-200) ng/mL respectively. PCT values $\geq$ 4.2 and 4.9 ng/ml were found to be the optimum cutoff value for the diagnosis of sepsis with bacteremia for Kryptor and VIDAS assay, respectively. In agreement with our findings, the cutoff value of 5 ng/mL was also employed by some studies to diagnose severe sepsis and septic shock[17-19]. Because of the difficulties in comparing individual studies and patient groups, it is difficult to determine an exact value of PCT for the diagnosis of sepsis. The cut-off values in different studies range from 0.5 to 5 ng/ml, with sensitivity ranging between 60 and 97% and specificity between 47.8 and 94%[20-26]. Values below 0.5 ng/ml are generally considered normal[27]. In the present study, however, the diagnostic performances were poor (AUROCC = 0.65-0.7) compared with the previous studies[9,16,28,29] in which AUROCCs ranged from 0.7 to 0.85. This is probably due to different patient populations especially of the non-bacteremic group as described above.

The results of this study corroborate that PCT correlated with severity of infections measured by APACHE II score and sepsis severity stratified by ACCP/SCCM criteria, as previously described[6,7]. The U.S. Food and Drug Administration (FDA) recently approved VIDAS and Kryptor PCT to be used in critically ill patients on the first day of ICU admission as an aid to assess their risk for progression to severe sepsis and septic shock. Interestingly, the initial PCT level did not predict mortality. These findings are in accordance with previous studies reporting that PCT levels per se poorly predicted outcome but decreasing levels were associated with a higher probability of survival[7,16,30,31]. This suggests that several PCT measurements should be made consecutively to

assess the critically ill patient's infection-related mortality risk (to monitor treatment of infection day-by-day).

To our knowledge, no previous study has evaluated the correlation between these three commercially available assays. One of the purposes of this study was to select the assay to be routinely used in Siriraj hospital. We found the good correlation among PCT levels measured by three different commercial assays. However, the levels measured by Kryptor assays were slightly lower than that measured by VIDAS, resulting in different optimum cutoff threshold between these two quantitative tests. The possible explanation will be discussed later. Despite lower levels of Kryptor PCT, the AUROCCs of both quantitative tests were comparable. This finding was confirmed by the study evaluated by BRAHMS. Therefore, we suggest that either of these two quantitative assays could be used as a diagnostic tool. Considering the PCT as a prognostic marker, it is desirable to have quantitative assays with a high upper detection limit to follow the treatment effects. In this regard, Kryptor is the preferred one among the three assays. In our series, five patients had VIDAS PCT concentration $\geq$ 200 ng/mL, four of which had PCT measured by Kryptor > 200 ng/mL with the highest level of 1,626 ng/mL. Lastly, A colorimetric, PCT-Q, has the advantage of rapid determination of circulating PCT levels in 30 minutes. Unfortunately, the assay is only semi-quantitative and is not sensitive enough to detect moderately elevated PCT levels. Thus, it may be useful primarily in emergency settings and mainly for diagnostic purposes.

Despite the previously mentioned advantages of this study, some limitations deserve careful consideration. Firstly, antibiotics are widely available over the counter in Thailand and medication history was sometimes difficult to verify. Being treated with antibiotics prior to admissions could potentially result in negative blood culture, despite persistently high PCT. As a result, ability to discriminate between bacteremic and non-bacteremic groups may be lower. Interestingly, AUROCCs of Kryptor and VIDAS were comparable but overall PCT levels measured by Kryptor assay were lower. This could be attributed to partial degradation during transportation. As mentioned earlier, three assays were carried out at two different institutions. Meisner M. et al demonstrated that repeated freezing-thawing cycles have no influence on PCT concentrations; however, at room temperature (25□C) a loss of PCT plasma concentrations of 6.4% $\pm$ 2.6% (mean $\pm$ 2 standard error of the mean) after 3 hours occurred[32]. Thereby, partial degradation during transportation possibly occurred and could explain the overall lower level and higher optimum cut-off value compared to VIDAS assay. Further studies to determine precisely the optimal Kryptor PCT thresholds to differentiate between bacteremic and non-bacteremic patients may be justified.

Conclusion

In the present study, PCT was highly sensitive in detecting bacteremia, although not very accurate in differentiating bacteremic from non-bacteremic SIRS in adult patients. In addition, there was an association between PCT levels and severity of infection measured by APACHE II score.

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Procalcitonin สำหรับการวินิจฉัยการติดเชื้อแบคทีเรียในกระแสเลือด

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วัตถุประสงค์: *เพื่อศึกษาความสามารถของ Procalcitonin (PCT) ในการวินิจฉัยการติดเชื้อแบคทีเรียในกระแสเลือดจากการวัด 3 เทคนิค ได้แก่ BRAHMS PCT Kryptor, VIDAS® BRAHMS PCT และ BRAHMS PCT-Q และดูความสัมพันธ์ของระดับ PCT กับความรุนแรงของโรค รวมทั้งเปรียบเทียบความสามารถในการวินิจฉัยของแต่ละวิธี*

วัสดุและวิธีการ: *การศึกษานี้เป็นแบบ Prospective study เก็บตัวอย่างเลือดจากผู้ป่วยที่มีภาวะ SIRS ร่วมกับการติดเชื้อ หรือ สงสัยว่าเกิดจากการติดเชื้อ ตั้งแต่เดือนสิงหาคมถึงพฤศจิกายน พ.ศ. 2550 โดยเก็บในวันแรกที่ได้รับการวินิจฉัย เพื่อวัดระดับ PCT ด้วยสามวิธีข้างต้น รวมทั้งเก็บเลือดเพื่อเพาะเชื้อแบคทีเรีย*

ผลการศึกษา: *ผู้ป่วยทั้งหมด 56 คน 30 คน มีการติดเชื้อในกระแสเลือด และ 26 คน มี SIRS แต่ไม่มีการติดเชื้อในกระแสเลือด การวัด PCT ทั้งสามวิธี ให้ผลสอดคล้องกัน ($p < 0.001$) ผลการตรวจ PCT ทั้งสามวิธีพบว่าผู้ป่วยกว่าร้อยละ 90 ที่มีเชื้อแบคทีเรียขึ้นในกระแสเลือดมีระดับ PCT $\geq$ 0.5 ng/mL กลุ่มที่มีผลเพาะเชื้อในเลือดเป็นบวกมีค่า median PCT ด้วยวิธี Kryptor และ VIDAS เท่ากับ 12.44 ng/mL (0.11-1626) และ 16.6 ng/mL (0.13-200) ตามลำดับ ในขณะที่กลุ่มที่ไม่มีเชื้อขึ้นในเลือด median PCT ด้วยวิธี Kryptor และ VIDAS เท่ากับ 4.15 ng/mL (0.04-184) และ 4.98 (0.05 - 200) ตามลำดับ ทั้งสองกลุ่มมีความแตกต่างกันทางสถิติทั้งสองวิธี ($p \leq 0.05$) ความสามารถในการแยกกลุ่ม bacteremia ออกจาก nonbacteremia ค่า cut off ที่ดีที่สุดของ Kryptor PCT และ VIDAS PCT คือ 5.0 และ 6.5 ng/mL ตามลำดับ โดยมีความไวและความจำเพาะ 73.3 และ 61.5 เท่ากันทั้งสองวิธี นอกจากนี้ยังพบว่าระดับ PCT มีความสัมพันธ์กับ APACHE II score และความรุนแรงของภาวะ sepsis อย่างมีนัยสำคัญทางสถิติ*

สรุป: *PCT มีความไวสูงมากในการวินิจฉัยการติดเชื้อในกระแสเลือด แต่ความสามารถในการแยกการติดเชื้อในกระแสเลือดจากภาวะ SIRS ร่วมกับการติดเชื้อเฉพาะที่ไม่ดีเท่าที่ควรนอกจากนั้นพบว่าผลที่ได้จากการวัดทั้งสามวิธีมีความสอดคล้องกัน*