Quick BSI Score to Identify Bloodstream Infection at the Emergency Department

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Abstract

Background: Bloodstream infection (BSI) is a common and urgent condition at the emergency department (ED). In order to diagnose BSI, the current guideline fails to mention the juncture at which blood cultures ought to be taken. The decision whether or not to obtain hemoculture is solely based upon clinical judgment and outcomes pertaining to inappropriately ordered blood culture. This study aimed to develop predictive bloodstream infection scoring at the ED employing only clinical factors presented on ED arrival.

Methods: This study was conducted retrospectively at the ED, Khon Kaen University Hospital, Thailand. Inclusion criteria encompassed adult patients suspected of infection defined by blood culture collection presented at the ED with intravenous antibiotics initiated during ED visits. Independent positive predictors for positive blood culture were used to create the Quick Bloodstream Infection score (qBSI score) through logistic regression analysis.

Results: A total of 169578 patients visited the ED during the study period. Of those, 12556 patients (7.40%) were suspected of infection. 8177 cases met the study criteria and were categorized according to positive blood culture results, i.e. bloodstream infection (741 patients; 9.06%). Probability of positive blood culture was calculated via aged over 55 years + moderate to severe CKD + solid organ tumor + (2 x liver disease) + (2 x history of fever with chills) + (2 x body temperature of over 38.3^{o}C). A score of 1 or over rendered 92.98% sensitivity, 15.40% specificity, 9.87% positive predictive value, 95.66% negative predictive value, positive likelihood ratio of 1.10, and negative likelihood ratio of 0.46.

Conclusions: The qBSI score may be a helpful tool to perform blood culture in patients at the ED suspected of infection. Employing this score may facilitate in the determining of those needing blood culture at the ED.

Background

Bloodstream infection (BSI) is a common as well as urgent condition at the emergency department (ED) [1,2]. Incidence of bloodstream infection increased to 38.1 persons per 100000 per year in 2010, while mortality rate may be as high as 50% [3]. Early diagnosis and appropriate antimicrobial therapy are a key to improve patient outcomes [4], particularly among individuals displaying either septic shock or sepsis [5,6].

Current guidelines advise on obtaining hemoculture in patients suspected of sepsis in order to diagnose BSI [5,7]. Positive blood culture is an important yield in terms of the appropriate antibiotics in sepsis patients [5,8]. However, the guideline fails to mention when blood cultures ought to be procured. Furthermore, the decision of whether or not to take hemoculture is based solely upon clinical judgment which could result in wastefulness resultant of inappropriately requested blood cultures [8-10]. Notwithstanding, there are several predictors of bloodstream infection at the ED, such as blood pressure less than 60 mmHg, a high procalcitonin level of over 2 µg/L, or C-reactive protein> 10 mg/dL [11].

Shapiro et al reported clinical scoring for bloodstream infection at the ED with a decent validation of 83% [12]. However, these previous reports may call for laboratory results to predict bloodstream infection at the ED. Unfortunately, this may result in delays in sepsis management on waiting for laboratory tests [6]. Hence, this study aimed to develop bloodstream infection predictive scoring at the ED using only clinical factors presented on ED arrival.

Methods

Study design and Ethical Approval

This study was conducted retrospectively at the ED, Khon Kaen University Hospital, a tertiary care hospital with approximately 60000 annual ED visits. Moreover, this study formed part of an ED infection project. Inclusion criteria were adult patients suspected of infection defined by blood culture collection at the ED with intravenous antibiotics initiated during ED visits. Cases demonstrating cardiac arrest or trauma; those referred from other hospitals; those who had received antibiotics prior; and those missing clinical data were excluded. The study period took place between January 1st, 2016 and December 31st, 2018 with study protocol approved by the ethics committee in human research, Khon Kaen University (HE631115). Informed consents were waived.

Source of data and Microbiology Methods

Blood cultures at the ED comprised of two aerobic bottles. Bloodstream infections were defined as positive blood culture with a similar pathogen to at least one sample with clinical relevance. The contaminated pathogens (e.g. coagulase-negative Staphylococci, Corynebacterium spp., Propionibacterium spp., Viridans group streptococci, Micrococcus spp. and Bacillus spp.) were considered as such if they were isolated from a patient twice or more consecutively with clinical relevance [7,13,14]. Clinical data of eligible patients were retrieved from the computerized hospital database and chart records. Data were subsequently categorized as comorbid conditions, ED arrival parameters, and beyond the initial hour following ED visit. Comorbid conditions were defined according to the Charlson Comorbidity Index (CCI) [15]. ED arrival parameters were history of fever, the chills, vital signs, and sepsis scores including Systemic Inflammatory Response Syndrome (SIRS), quick Sepsis-related Organ Failure Assessment (qSOFA) and National Early Warning Score (NEWS). For parameters beyond the initial hour post ED visit, laboratory results incorporated white blood cell count and lactate level.

Statistical Analysis

In regards statistical analyses eligible patients were categorized into two groups with respect to blood culture results: positive blood culture and negative blood culture groups. Descriptive statistics were used to compare differences in studied variables between both groups. Factors associated with positive blood culture were calculated via logistic regression analysis. A univariate and multivariate logistic regression was applied to calculate unadjusted/adjusted odds ratio (95% confidence interval) of each factor. There

were two models to predict positive blood culture at the ED: using all studied variables (Table 2) and using only initial parameters (Table 3). Independent positive predictors for positive blood culture at initial ED presentation were utilized to create the Quick blood stream infection score (qBSI score). Clinical factors excluding laboratory results were used for the qBSI score with the aim of identifying bloodstream infections faster minus the wait for laboratory results. Each predictor presented a clinical score based on the coefficient yielded by the final model for positive blood culture. The qBSI score revealed summation of each predictor. Various qBSI score cutoff points were executed and reported along with diagnostic properties including sensitivity, specificity, positive/negative predictive values (PPV/ NPV), and positive/negative likelihood ratios (LR+/LR-). A receiver operating characteristic (ROC) curve of the qBSI score was computed and compared with other sepsis scores. All statistical analyses were performed using STATA software, version 10.1 (College Station, Texas, USA).

Results

Patient Characteristic and Microbiology Data

A total of 169578 patients visited the ED during the study period as retrieved from the hospital database. Of those, 12556 (7.40%) were suspected of infection. After exclusion, 8177 individuals met the study criteria and were categorized according to blood culture results as follows: positive bloodstream infection (741 patients; 9.06%) and negative blood culture or non-pathogen bacteremia (7436 patients; 90.94%) as shown in Figure 1. Among the variables studied, almost all were significantly different between both groups (Table 1). Merely proportion of AIDS was not significantly different between groups (2.16% in positive blood culture group and 1.44% in negative blood culture group; p 0.125). The most common Gram negative and positive pathogens were Escherichia coli (274 patients; 36.98%) and Streptococcus (76 patients; 10.26%).

Table 1. Baseline characteristics of patients with suspected infection presenting at the emergency department categorized by blood culture results.

	ALL patients (n = 8177) n (%)	Positive blood culture (n = 741) n (%)	Negative blood culture (n = 7436) n (%)	p-value
Demographics				
Age, yrs. –median (range)	62 (18-100)	62 (18-100)	64 (18-100)	<0.001
Male	4275 (52.28)	415 (56.01)	3860 (51.90)	0.003
CCI –median (range)	3 (0-13)	4 (0-13)	3 (0-13)	<0.001
Comorbidity				
Age > 55 years	5231 (63.97)	537 (72.47)	4694 (63.13)	<0.001
Hypertension	2149 (26.28)	235 (31.71)	1914 (25.74)	<0.001
Solid organ malignancy	1878 (22.97)	231(31.17)	1647 (22.15)	<0.001
Diabetes mellitus	1729 (21.14)	194 (26.18)	1535 (20.64)	<0.001
Liver disease	1190 (14.55)	191 (25.78)	999 (13.43)	<0.001
Moderate to severe CKD	639 (7.81)	86 (11.61)	553 (7.44)	<0.001
AIDS	123 (1.50)	16 (2.16)	107 (1.44)	0.125
History of chills	515 (6.30)	101 (13.63)	414 (5.57)	<0.001
Clinical presentation at triage zone				
Respiratory rate > 22/min	5369 (65.66)	573 (77.33)	4796 (64.50)	<0.001
Temperature > 38.3^{o}C	2658 (32.51)	349 (47.10)	2309 (31.05)	<0.001
Heart rate > 120/min	921 (11.26)	105 (14.17)	816 (10.97)	<0.001
Hypotension (SBP < 90 or MAP < 65 mmHg)	611 (7.47)	96 (12.96)	515 (6.93)	<0.001
Met Sepsis criteria				
SIRS ≥ 2	6149 (75.20)	651 (87.85)	5498 (93.94)	<0.001
qSOFA ≥2	1230	140 (18.89)	1060 (14.25)	<0.001

	(15.04)			
NEWS ≥ 7	2917 (35.67)	259 (34.95)	1759 (23.66)	<0.001
Lactate values	(n = 4694)	(n = 575)	(n = 4119)	
First lactate, mmol/L-median	1.88 (0.01-28.33)	2.50 (0.01-18.71)	1.80 (0.01-28.33)	<0.001
First lactate > 2 mmol/L	2193 (46.72)	383 (51.69)	1810 (23.34)	<0.001

CKD: chronic kidney disease; SBP: systolic blood pressure; MAP: mean arterial pressure; SIRS: Systemic Inflammatory Response Syndrome; qSOFA: quick Sepsis-related Organ Failure Assessment; NEWS: National Early Warning Score.

Clinical factors and calculation of Quick Bloodstream Infection score (qBSI score)

Among three categories of studied variables, there were four significant factors in comorbid conditions, two factors at ED, and three factors beyond the 1st hour (Table 2). The six significant predictors for positive blood cultures were age over 55 years, moderate to severe CKD, solid organ tumor, liver disease, history of chills, and body temperature of over 38.3oC. The scores of each parameter were shown in Table 3 with the total score of 9. The probability of positive blood culture calculated by age over 55 years + moderate to severe CKD + solid organ tumor + (2 x liver disease) + (2 x history of fever with chills) + (2 x body temperature of over 38.3^{o}C). If the parameter was absent or present, the values of the parameter were 0 or 1, respectively. The sum of all parameters represented probability of positive blood culture. A cutoff point of this qBSI score of 1 or over had sensitivity, specificity, PPV, NPV, LR+, and LR- of 92.98% (90.90%-94.71%), 15.40% (14.58%-16.24%), 9.87% (9.68%-10.07%), 95.66% (94.40%-96.64%), 1.10 (1.08-1.12), and 0.46 (0.35-0.60), respectively (Table 4). The ROC of qBSI score (0.66; 0.64-0.68) as shown in Figure 2.

Table 2. Factors associated with positive blood culture in patients suspected of infection presenting at the emergency department.

Factors	Unadjusted Odds Ratio (95% CI)	*Adjusted Odds Ratio (95% CI)	p-value
Comorbid conditions			
Age > 55	1.54 (1.30-1.81)	1.33 (1.04-1.72)	0.02
Sex	0.84 (0.73-0.99)	0.94 (78.1-1.13)	0.52
Emergency severity index level	0.62 (0.55-0.70)	0.87 (0.71-1.13)	0.18
CCI	1.13 (1.09-1.06)	0.98 (0.92-1.04)	0.46
Liver disease	2.24 (1.87-2.67)	2.04 (1.59-2.61)	<0.01
Diabetes mellitus	1.36 (1.15-1.62)	1.08 (0.89-1.30)	0.45
Moderate to severe CKD	1.63 (1.28-2.08)	1.68 (1.22-2.32)	0.01
Solid organ tumor	1.59 (1.35-1.87)	1.40 (1.09-1.80)	0.01
Hypertension	1.34 (1.13-1.57)	1.14 (0.92-1.41)	0.24
On arrival parameter			
History of Chills	2.67 (2.12-3.38)	1.94 (1.43-2.62)	<0.01
Temperature > 38.3°C	1.40 (1.32-1.50)	1.77 (1.39-2.25)	<0.01
Heart rate >120 /min	1.01 (1.00-1.01)	0.96 (0.73-1.26)	0.76
SBP < 90 or MAP < 65	2.01 (1.59-2.54)	1.22 (0.86-1.71)	0.26
Respiratory rate > 22/min	1.03 (1.02-1.04)	0.89 (0.71-1.26)	0.32
SIRS criteria $\geq$ 2	2.5 (2.03-3.20)	1.21 (0.94-1.53)	0.26
qSOFA criteria $\geq$ 2	1.79 (1.49-2.15)	1.20 (0.94-1.53)	0.15
NEWS $\geq$ 7	1.73 (1.47-2.04)	0.93 (0.73-1.18)	0.53
Beyond first hour parameter			
**Lactate level	1.13 (1.10-1.16)	1.10 (1.07-1.14)	<0.01
WBC > 11,000 /microliter	1.31 (1.12-1.52)	1.28 (1.03-1.59)	0.03
WBC < 3,000 /microliter	2.30 (1.70-3.13)	2.48 (1.68-3.66)	<0.01

CCI: Charlson Comorbidity Index; CKD: chronic kidney disease; SBP: systolic blood pressure; MAP: mean arterial pressure; SIRS: Systemic Inflammatory Response Syndrome; qSOFA: quick Sepsis-related Organ Failure Assessment; NEWS: National Early Warning Score; WBC: white blood cell.

*adjusted odds ratios shown in the table indicated adjusted by the studied factors shown in this table.

** lactate level is initial lactate level in mmol/L.

Table 3. Individual and adjusted odds ratio of component of the Quick Bloodstream Infection score (qBSI score) predicting positive blood culture in patients with suspected infection presenting at the emergency department.

Factors	Score	Adjusted Odds Ratio (95% Confidence Interval)	p-value
Comorbid conditions			
Age > 55	1	1.33 (1.04-1.72)	0.02
Moderate to severe CKD	1	1.68 (1.22-2.32)	0.01
Solid organ tumor	1	1.40 (1.09-1.80)	0.01
Liver disease	2	2.04 (1.59-2.61)	<0.01
On arrival parameter			
History of chills	2	1.94 (1.43-2.62)	<0.01
Temperature > 38.3°C	2	1.77 (1.39-2.25)	<0.01

CKD: chronic kidney disease.

* adjusted odds ratios shown in the table indicated adjusted by the studied factors shown in the table 2.

Table 4. diagnostic properties of the Quick Bloodstream Infection score (qBSI score) predicting positive blood culture in patients with suspected infection presenting at the emergency department.

Scores	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	+LR	-LR
Score ≥ 0	100.00%	0.00%	9.06%		1.00	
Score ≥ 1	92.98%	15.40%	9.87%	95.66%	1.10	0.46
Score ≥ 2	75.84%	43.69%	11.83%	94.78%	1.35	0.55
Score ≥ 3	59.65%	65.42%	14.67%	94.21%	1.73	0.62
Score ≥ 4	36.17%	84.29%	18.66%	92.98%	2.30	0.75
Score ≥ 5	21.59%	93.50%	24.88%	92.29%	3.32	0.84
Score ≥ 6	9.99%	98.00%	33.18%	91.61%	4.98	0.92
Score ≥ 7	2.29%	99.61%	36.96%	91.10%	5.88	0.98
Score ≥ 8	1.08%	99.83%	38.1%	91.00%	6.18	0.99
Score ≥ 9	0.27%	100.00%	100.0%	90.96%		1.00

Note. PPV: positive predictive value; NPV: negative predictive value; +LR: positive likelihood ratio, -LR: negative likelihood ratio

Discussion

The qBSI score, to our knowledge, is the first score to quickly identify bloodstream infection at the ED, minus the wait for additional laboratory results. The advantage of this score is that the risk of bloodstream infection at the ED can be calculated speedily and easily using clinical formulae mentioned in the results. Also, it demonstrates an ample sensitivity of 92.98% with high negative predictive value. These results may indicate that a qBSI score of 1 or over could be attributable to a high chance of

exhibiting bloodstream infection. Conversely, those recording a qBSI score of 0 present a low risk of bloodstream infection (NPV 95.66%), in which case, blood cultures may not be required. Based on specificity, 15.40% of all blood cultures could be avoided, though 52 patients (7% of total patients) with blood stream infection would have been overlooked. Using the qBSI score may help clinicians reduce the amount of unnecessary blood culture collection and present cost benefits. Nevertheless, it sacrifices some false-negative diagnostic BSI and may result in inappropriate antibiotic prescription. Careful clinical judgment must be employed when applying this diagnostic score amid practice due to its imperfect diagnostic value.

As sepsis scores are prognostic tools but not diagnostic scores for bloodstream infections [16, 17], the qBSI score has diagnostic values for bloodstream infections. Despite some laboratory tests including lactate or white blood cells, they were independent factors in terms of bloodstream infection (Table 3), and they were not included in the qBSI score to save time amid the identifying of patients at risk of bloodstream infection. These results also indicate that laboratory tests for sepsis scores were ample parameters amid bloodstream infection. Yet, once again, this may delay the sepsis treatment bundle [6].

The positive blood culture rate in this study was comparable with previous studies: 9.06% (up to 12.4%) [11,18]. Inappropriate blood cultures obtained from patients at a low risk may yield false positives as well as antibiotic overuse [18]. Besides that, the qBSI score may be a helpful tool in correctly identifying patients likely to display positive blood culture, as previously discussed. Even though this study revealed different predictors to previous studies [19,20], these factors were reported to be associated with positive blood cultures [21,25]. For example, cirrhosis patients demonstrated a superior incidence of bloodstream infection over non-cirrhotic patients throughout ten instances [24]. As this study included only comorbid conditions and ED factors, these may result in different predictors of positive blood culture to other studies.

Strengths and limitations

This study showed that the qBSI score presented good sensitivity and negative predictive value for positive blood culture in patients attending the ED with suspicion of infection. The score comprised of six clinical variables minus laboratory results. As it does not include laboratory results, the score may facilitate a physician’s decision to rapidly perform blood culture. Notwithstanding, there are some limitations amid this study. Even though the study incorporated quite a large sample size, some clinical data may be missing due to the retrospective study design. Those with missing data were excluded (261 patients) and not included in the analysis. Second, blood culture was performed per decision by the attending physicians at a single ED. Further studies are then required to validate and confirm the results of this study. Finally, score specificity was not high as previously reported by Shapiro et al. [12]. Still, sensitivity is of superior importance in this situation and those exhibiting bloodstream infections ought not to be overlooked. Additionally, the qBSI score is a speedier clinical tool than the Shapiro report, that is to say, the qBSI score can be calculated within minutes following ED arrival.

Conclusions

The qBSI score may be a helpful tool to perform blood culture in patients at the ED suspected of infection. This score can be calculated within minutes at the ED in patients at risk of bloodstream infection once a complete medical history and physical examination have occurred, minus laboratory results. Employing this score may facilitate in the determining of those needing blood culture at the ED.

Abbreviations

AUROC: associated area under the ROC

BSI: bloodstream infection (BSI)

CCI: Charlson Comorbidity Index

CKD: chronic kidney disease

ED: emergency department

+LR: positive likelihood ratio

-LR: negative likelihood ratio

MAP: mean arterial pressure

NEWS: National Early Warning Score

qBSI score: Quick Bloodstream Infection score

ROC curve; receiver operating characteristic curves

SIRS: Systemic Inflammatory Response Syndrome (SIRS)

SBP: systolic blood pressure.

Declarations

Ethics approval and consent to participate

The study period took place between January 1st, 2016 and December 31st, 2018 with study protocol approved by the ethics committee in human research, Khon Kaen University (HE631115). Informed consents were waived.

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Author Contributions

Conceptualization and Methodology: P.P., N.L. and K.A.; data validation: P.P., N.L. and K.I.; data curation and investigation: P.P., K.A. and S.S.; writing—original draft and formal analysis: P.P., K.S. and V.C.; writing—review and editing: All authors; supervision: P.P. and K.A. All authors have read and agreed to the published version of the manuscript.

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Competing interests

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Figures

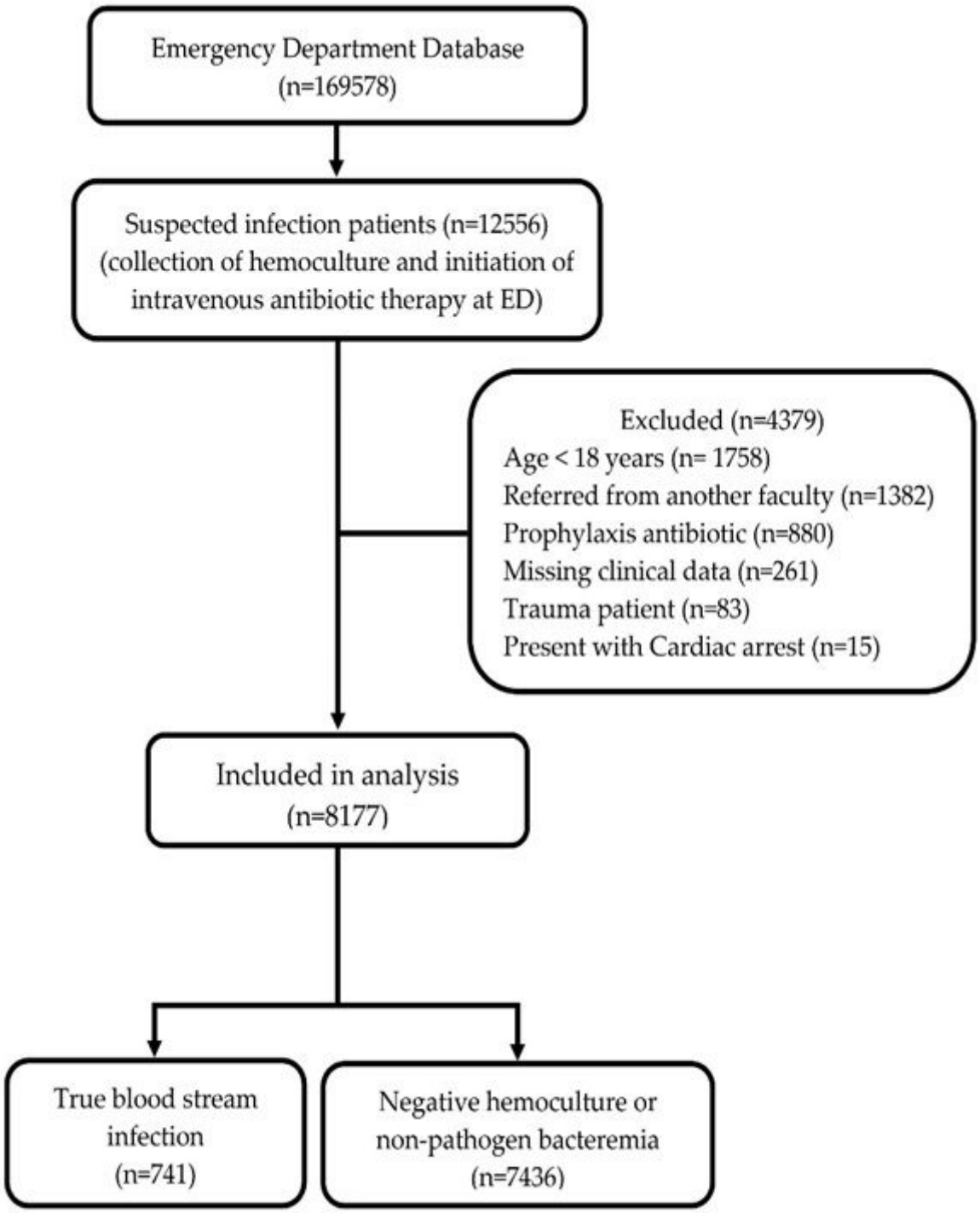
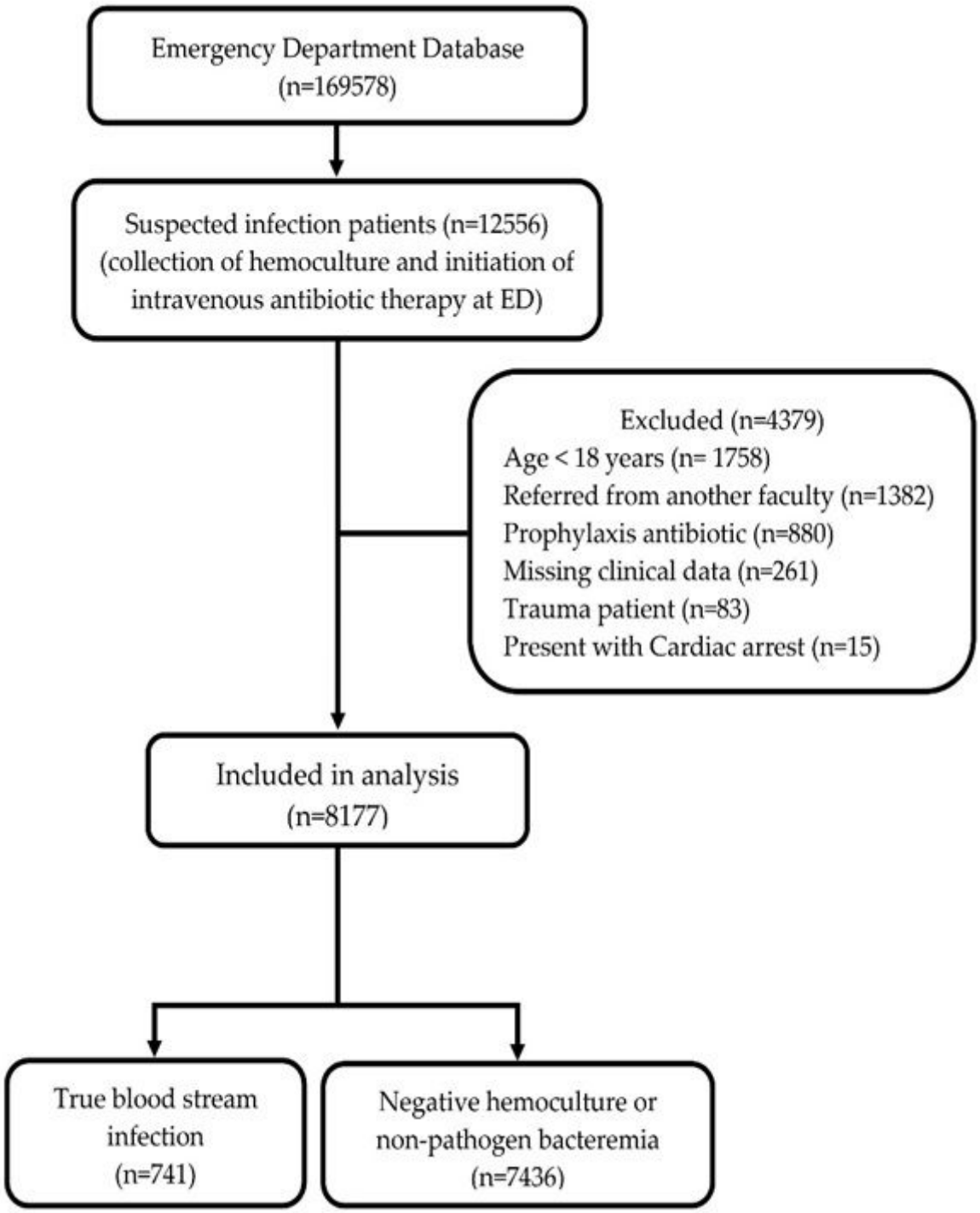


Figure 1

Study flow of patients with suspected infection presenting at the emergency department and blood culture results.



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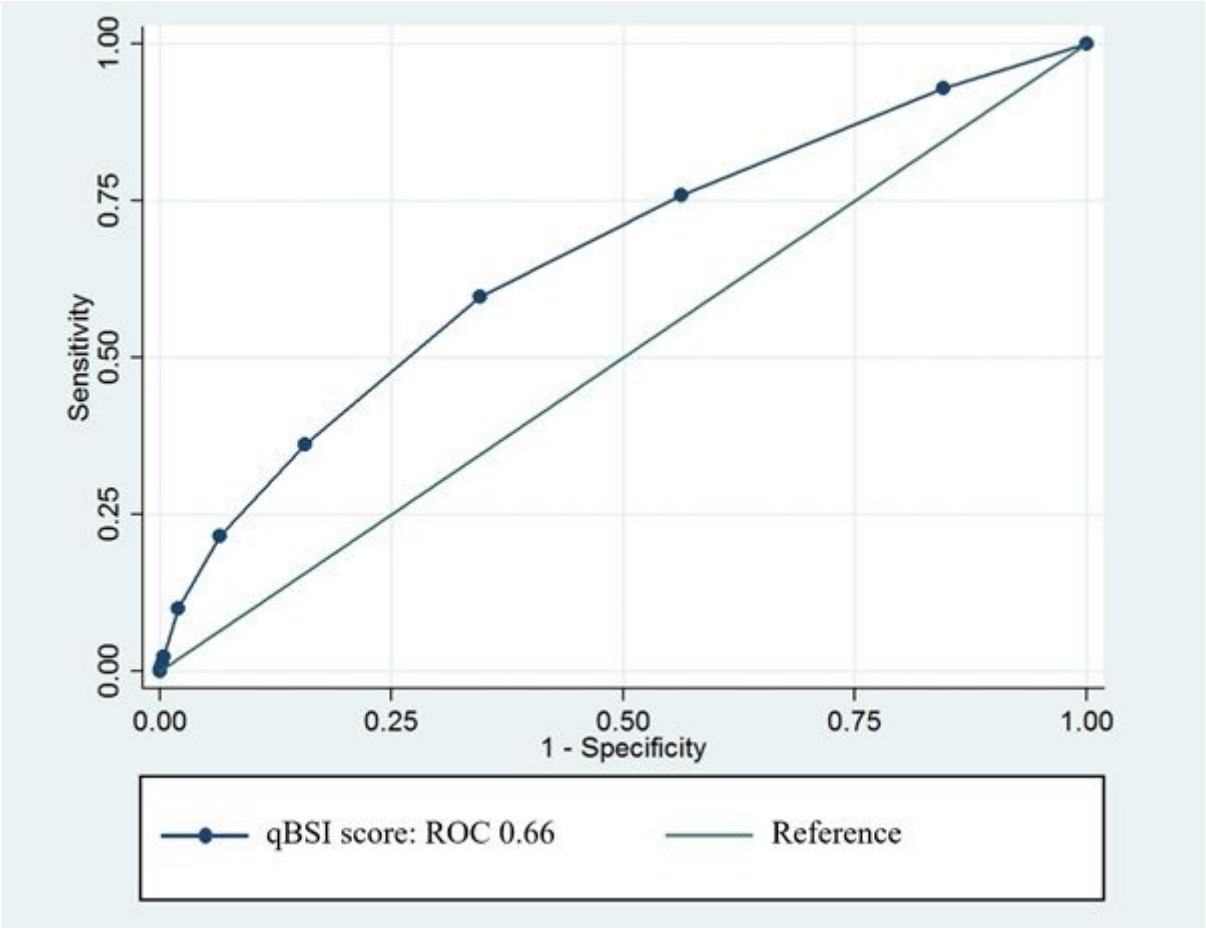
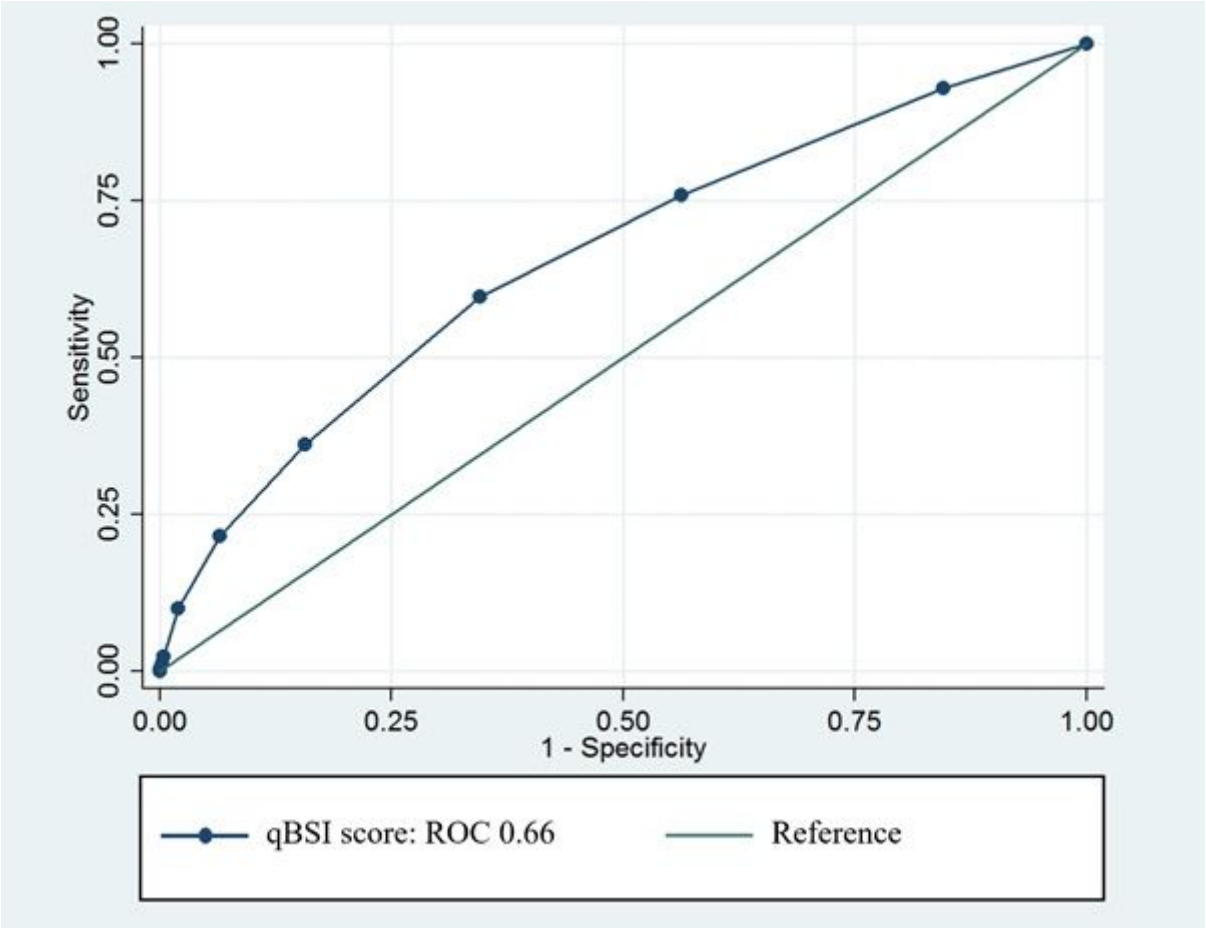


Figure 2

The receiver operating characteristic (ROC) curves of the Quick Bloodstream Infection score (qBSI score) predicting positive blood culture in patients with suspected infection presenting at the emergency department. qBSI: Quick Bloodstream Infection score



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