VIA MEDICA

ORIGINAL AND CLINICAL ARTICLES

Anaesthesiology Intensive Therapy
2016, vol. 48, no 3, 175–179
ISSN 1642–5758
10.5603/AIT.a2016.0030
www.ait.viamedica.pl

Predictive value of the APACHE II, SAPS II, SOFA and GCS scoring systems in patients with severe purulent bacterial meningitis

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Abstract

Background: Scoring systems in critical care patients are essential for predicting of the patient outcome and evaluating the therapy. In this study, we determined the value of the Acute Physiology and Chronic Health Evaluation II (APACHE II), Simplified Acute Physiology Score II (SAPS II), Sequential Organ Failure Assessment (SOFA) and Glasgow Coma Scale (GCS) scoring systems in the prediction of mortality in adult patients admitted to the intensive care unit (ICU) with severe purulent bacterial meningitis.

Methods: We retrospectively analysed data from 98 adult patients with severe purulent bacterial meningitis who were admitted to the single ICU between March 2006 and September 2015.

Results: Univariate logistic regression identified the following risk factors of death in patients with severe purulent bacterial meningitis: APACHE II, SAPS II, SOFA, and GCS scores, and the lengths of ICU stay and hospital stay. The independent risk factors of patient death in multivariate analysis were the SAPS II score, the length of ICU stay and the length of hospital stay. In the prediction of mortality according to the area under the curve, the SAPS II score had the highest accuracy followed by the APACHE II, GCS and SOFA scores.

Conclusions: For the prediction of mortality in a patient with severe purulent bacterial meningitis, SAPS II had the highest accuracy.

Key words: Acute Physiology and Chronic Health Evaluation II; Bacterial meningitis; Glasgow Coma Scale; Risk factors of death; Sequential Organ Failure Assessment, Simplified Acute Physiology Score II

Anaesthesiology Intensive Therapy 2016, vol. 48, no 3, 175–179

Bacterial meningitis is a life-threatening infectious disease that affects over one million people yearly, with higher incidence rates among developing countries and in specific geographic areas [1]. Bacterial meningitis kills or maims approximately a fifth of the individuals with the disease. Irrespective of advances in pharmacotherapy and intensive care, acute bacterial purulent meningoencephalitis remains a condition of uncertain prognosis and relatively high mortality [2–7].

Common pathogens encountered in adult meningitis include *Streptococcus pneumoniae*, other *Streptococcus* species, *Staphylococcus* species, *Neisseria meningitidis*, *Haemophilus influenzae*, Gram-negative bacilli and *Listeria monocytogenes* [8–13]. The epidemiology of bacterial meningitis has changed as a result of the widespread use of conjugate vaccines and the preventive antimicrobial treatment of pregnant women [11].

Bacterial meningitis may develop as purulent or non-purulent inflammation. Types of non-purulent bacterial meningitis include tuberculous meningitis, neuroborreliosis and encephalitis, which occur in the course of leptospirosis, syphilis, tularaemia, brucellosis, anaplasmosis and ehrlichiosis. A slightly different course of inflammation occurs in the case of *Listeria monocytogenes* infection, which typically causes purulent bacterial meningitis and rarely leads to encephalitis and/or brain stem encephalitis, often accompanied by rhombencephalitis and brain abscesses [14].

In Poland, the majority of adult patients with purulent bacterial meningitis are hospitalized in infectious disease departments. However, a significant percentage of patients with severe purulent bacterial meningitis require hospitalization in intensive care units (ICUs).

The aim of this report was to assess the abilities of the Acute Physiology and Chronic Health Evaluation II (APACHE II), Simplified Acute Physiology Score II (SAPS II), Sequential Organ Failure Assessment (SOFA) and Glasgow Coma Scale (GCS) scoring systems to predict mortality in adult patients admitted to the ICU with severe purulent bacterial meningitis.

METHODS

The study was approved by the Bioethics Committee of the Medical University of Łódź, PL (RNN/241/15/KB). Given the retrospective nature of this study and according to Polish law, no informed consent was required.

We retrospectively analysed data from 98 adult patients with severe purulent bacterial meningitis who were admitted to the Department of Anaesthesiology and Intensive Therapy between March 2006 and September 2015.

The analysis covered demographic (age and sex), clinical data (primary diagnosis; concomitant diseases and illnesses; the time from the onset of symptoms to hospital admission; the time from the onset of symptoms to the time of ICU admission; the GCS score on admission to the unit; APACHE II, SAPS II and SOFA scores on the first day of treatment; the type of pathogen causing purulent meningitis; the length of ICU stay; and the length of hospital stay) and cerebrospinal fluid examinations. APACHE II, SAPS II and SOFA scores were determined using an online calculator.

STATISTICAL ANALYSIS

An analysis of the results was conducted using the statistical package PQStat ver. 1.6 (PQStat Software, Poznań, Poland). The predictive ability of the analysed scales in relation to the prediction of mortality in patients was analysed using logistic regression models and receiver operating characteristic (ROC) curve analysis. Test probability was assumed to be significant at $P < 0.05$.

RESULTS

A total of 1,460 patients were admitted to the Department of Anaesthesiology and Intensive Therapy, during the greater than ten-year study period. Ninety-eight patients with severe purulent bacterial meningitis (6.71% of the ICU admissions) were included in the study. The patients' mean age was 55 ± 15 years. Sixty-one (62.24%) of the patients were men. The following predisposing conditions were observed: alcohol use disorders, diabetes mellitus, the use of immunosuppressive drugs, neurosurgery, head trauma, cancer, renal failure, chronic hepatitis with cirrhosis, sinusitis and otitis, previous episodes of bacterial meningitis and liquorrhoea. At ICU admission, the median (IQR) APACHE II, SAPS II, SOFA and GCS scores were 25 (19–30), 56 (38–69), 10 (7–12) and 6 (3–8), respectively. The median length of ICU stay was 10 days (IQR 5–20.25), and ICU mortality was 44.90%. Clinical characteristics and laboratory findings for the cerebrospinal fluid of adult patients with severe purulent bacterial meningitis are included in Tables 1 and 2.

The pathogens that most frequently caused severe purulent bacterial meningitis were *Streptococcus pneumoniae* (38.78%), *Listeria monocytogenes* (8.16%) and *Staphylococci* (8.16%). Detailed data on the identified pathogens are presented in Table 3.

Univariate logistic regression identified the following risk factors of death in patients with severe purulent bacterial meningitis: APACHE II ($P < 0.0001$), SAPS II ($P < 0.0001$), SOFA ($P = 0.0024$), and GCS ($P = 0.0003$) scores and the lengths of ICU stay ($P = 0.0273$) and hospital stay ($P = 0.0280$). The independent risk factors of patient death according to multivariate analysis were the SAPS II score ($P = 0.0433$; OR 1.11 [95% confidence interval (CI): 1.00–1.24]), the length of ICU stay ($P = 0.0031$; OR 1.60 [95% CI: 1.17–2.18]), and the length of hospital stay ($P = 0.0052$; OR 0.67 [95% CI: 0.50–0.89]).

In the prediction of mortality according to the area under the curve (AUC), the SAPS II (area under the curve (AUC) 0.81; 95% CI: 0.72–0.90; $P < 0.0001$) scoring system had the highest accuracy (Fig. 1), followed by the APACHE II (AUC 0.79; 95% CI: 0.70–0.88; $P < 0.0001$), GCS (AUC 0.72; 95% CI: 0.62–0.82; $P = 0.0002$) and SOFA (AUC 0.69; 95% CI: 0.58–0.80; $P = 0.0017$) scoring systems.

DISCUSSION

Despite the availability of effective antibiotics, vaccination programmes and skilled acute-care facilities, bacterial meningitis still results in significant mortality and morbidity.

Patients with meningitis account for approximately 1% of patients hospitalized in ICUs [15]. At the Department of Anaesthesiology and Intensive Therapy, this percentage is several times larger. This increase is caused by the fact that each patient in the Łódź region who is diagnosed with meningitis and requires intensive care is directed to a reference ICU treating patients with infectious diseases, i.e., to the Department of Anaesthesiology and Intensive Therapy.

Our study presents a cohort of 98 adult ICU patients with severe purulent bacterial meningitis. *Streptococcus pneumoniae* was the most prevalent causative microorganism. *Streptococcus pneumoniae* is now the most common aetiological agent of bacterial meningitis in the United States and Europe, accounting for 61% of all cases in the United States [10, 16].

Table 1. Clinical characteristics of patients (n = 98)

Variable	Value
Age (years), mean ± SD	55 ± 15
Male sex, n (%)	61 (62.24)
ICU mortality, n (%)	44 (44.90)
Predisposing factor, n (%)	67 (68.37)
Alcohol use disorders	29 (29.59)
Diabetes mellitus	15 (15.31)
Use of immunosuppressive drugs	2 (2.04)
Neurosurgery	3 (3.06)
Head trauma	11 (11.22)
Cancer	9 (9.18)
Renal failure	4 (4.08)
Chronic hepatitis with cirrhosis	6 (6.12)
Sinusitis and otitis	6 (6.12)
Previous episode of bacterial meningitis	5 (5.10)
Liquorrhoea	2 (2.04)
Cause of hospitalization at ICU, n (%)	
Coma (GCS ≤ 8)	74 (75.51)
Respiratory failure	63 (64.29)
Respiratory and circulatory failure	32 (32.65)
Multiorgan failure	1 (1.02)
Renal failure	1 (1.02)
Time from the onset of symptoms to hospital admission (days), median (IQR)	
All	1 (0.25–4)
Patients who survived the stay in the ICU	1 (0.2–3)
Patients who died during hospitalization in the ICU	1 (0.5–4)
Time from the onset of symptoms to ICU admission (days), median (IQR)	
All	3 (1–6)
Patients who survived the stay in the ICU	2 (1–5)
Patients who died during hospitalization in the ICU	4 (1–8.75)
Length of ICU stay (days), median (IQR)	
All	10 (5–20.25)
Patients who survived the stay in the ICU	10 (4.75–15.25)
Patients who died during hospitalization in the ICU	13 (6.25–29.25)
Length of hospital stay (days), median (IQR)	
All	24 (12.75–36.5)
Patients who survived the stay in the ICU	27 (19–39)
Patients who died during hospitalization in the ICU	15 (7.25–31.25)
APACHE II score*, median (IQR)	
All	25 (19–30)
Patients who survived the stay in the ICU	20.5 (15–26)
Patients who died during hospitalization in the ICU	29 (25–32)
SAPS II score*, median (IQR)	
All	56 (38–69)
Patients who survived the stay in the ICU	45.5 (32.25–57)
Patients who died during hospitalization in the ICU	63 (55–74)
SOFA score day 1*, median (IQR)	
All	10 (7–12)
Patients who survived the stay in the ICU	9 (6–11)
Patients who died during hospitalization in the ICU	10 (9–13)
GCS score*, median (IQR)	
All	6 (3–8)
Patients who survived the stay in the ICU	7 (5–11)
Patients who died during hospitalization in the ICU	4 (3–6)

* n = 95; abbreviations explained in text

Table 2. Laboratory findings on the cerebrospinal fluid of patients with purulent bacterial meningitis at ICU admission (n = 95)

Index of CSF inflammation	Value
WBC count, n (%)	
< 100 cells mm^{-3}	15 (15.75)
100–999 cells mm^{-3}	37 (38.95)
> 1000 cells mm^{-3}	43 (45.26)
Protein concentration (mg dL^{-1}), median (IQR)	455 (223–753)
CSF glucose concentration (mg dL^{-1}), median (IQR)	0.07 (0.01–0.25)

CSF — cerebrospinal fluid; IQR — interquartile range; WBC — white blood cells

Table 3. Pathogens identified in the cerebrospinal fluid that caused severe purulent bacterial meningitis requiring hospitalization in an intensive care unit (n = 98)

Pathogen	Number of cases, n (%)	Number of deaths, n (%)
Streptococcus pneumoniae	38 (38.78)	17 (38.64)
Other *Streptococci*	3 (3.06)	1 (2.27)
Neisseria meningitidis	4 (4.08)	1 (2.27)
Staphylococci	8 (8.16)	4 (9.09)
Actinomyces naeslundii	1 (1.02)	0 (0.00)
Escherichia coli	2 (2.04)	1 (2.27)
Acinetobacter baumannii	4 (4.08)	4 (9.09)
Listeria monocytogenes	8 (8.16)	5 (11.36)
Kocuria rosea	1 (1.02)	0 (0.00)
Cryptococcus neoformans	1 (1.02)	0 (0.00)
Not detected	28 (28.57)	11 (25.00)
Total	98 (100)	44 (100)

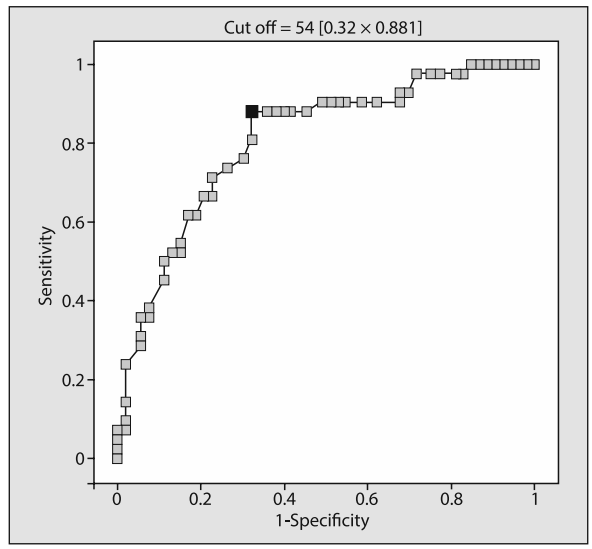

Figure 1. A ROC curve for the SAPS II predictor

In the greater than ten-year period covered by this study, 38 patients were hospitalized with severe bacterial purulent bacterial meningitis caused by *Streptococcus pneumoniae*. Seventeen of these patients died. The statistical data on the incidence of bacterial meningitis caused by *Streptococcus pneumoniae* in the Łódź region (but also in Poland as a whole) are alarming.

According to the Polish National Institute of Hygiene, 195 cases of meningitis and/or encephalitis caused by *Streptococcus pneumoniae* were recorded in 2013 (incidence rate of 0.51 per 100,000 population) [17]. During this period in the Łódź region, 19 cases of meningitis caused by *Streptococcus pneumoniae* were recorded (incidence rate of 0.75 per 100,000 population) [18]. All these patients were hospitalized, including six at the Department of Anaesthesiology and Intensive Therapy (31.58%). In 2014, 194 cases of meningitis and/or encephalitis caused by *Streptococcus pneumoniae* were recorded in Poland (incidence rate of 0.50 per 100,000 population) [17]. During this period in the Łódź region, 21 cases of meningitis caused by *Streptococcus pneumoniae* were recorded (incidence rate of 0.8 per 100,000 population) [17]. In this case, all patients were hospitalized, including nine at the Department of Anaesthesiology and Intensive Therapy (42.86%). Could the epidemiological situation improve soon? An improvement does not seem very likely. In 2013 in Poland, 201,231 people were vaccinated against *Streptococcus pneumoniae* [18]. According to the Immunization Programme for 2013, vaccination against *Streptococcus pneumoniae* was mandatory only for children aged 2 months to 5 years of age within high-risk groups with specific medical indications [18]. For obvious reasons, the effects of the programme will be visible only after a long period of time. To significantly reduce mortality in the population as a whole, particularly among persons aged 41 to 70 years, it is advisable to extend the scope of mandatory vaccination.

Listeria monocytogenes was the second most common pathogen causing purulent bacterial meningitis. In 7 out of 8 patients, at least one risk factor of meningitis was identified.

Half of the patients with acute bacterial meningitis have predisposing conditions, and one-third of these patients have an immunodeficiency [10]. Alcoholism, human immunodeficiency virus (HIV) infection, diabetes mellitus, the use of immunosuppressive drugs, asplenia, and cancer may cause dysfunction of the immune system, thereby increasing the risk of invasive infections, including meningitis [19–21]. Several risk factors are associated with meningitis, such as age, gender, otitis or sinusitis, neurosurgery, alcoholism, diabetes mellitus, splenectomy, renal failure, chronic hepatitis with cirrhosis, endocarditis, cerebrospinal fluid rhinorrhoea, dural fistulas, and head trauma [10, 11, 22, 23]. Our study identified risk factors associated with meningitis in 67 patients (68.37%; see Table 1). The most commonly occurring risk factor was alcoholism, which was identified in 29 patients.

Patients with purulent meningitis hospitalized in ICUs rarely arrive at these departments without prior hospitalization in medical wards. Only severe neurological complications and dysfunctions of the respiratory and/or circulatory system make it necessary to transfer the patient to an ICU. The mortality rate in the subpopulation of purulent meningitis patients with a significant dysfunction of one or several organs is, for obvious reasons, increased compared with a subpopulation in which no such dysfunction occurs or the entire population of patients with purulent meningitis.

The APACHE II, SAPS II and SOFA scoring systems are used in everyday work at ICUs. Our results suggest that the SAPS II and APACHE II scoring systems are the best at predicting mortality in patients with severe purulent bacterial meningitis, whereas the SOFA scoring system is a little poorer at predicting mortality. The risk of death can be more accurately estimated on the basis of the maximum score on the SOFA scale during the patient's ICU stay.

Fernandes *et al.* performed a retrospective analysis during a seven-year period in patients older than 18 years of age admitted to two polyvalent ICUs. The researchers identified 65 patients with a diagnosis of acute bacterial meningitis. The mean APACHE II score was 23, and hospital mortality was 40%. Our results concerning patient mortality and clinical condition assessed on the APACHE II scale are similar to those presented by Fernandes *et al.* [24].

The overall in-hospital mortality rate in severe community-acquired septic meningitis in adults typically varies between 15 and 40%, although it can be as high as 77.5% [7, 10, 16, 24–27]. The reported mortality rate depends, among other factors, on the type of the pathogen causing purulent bacterial meningitis and the frequency of its occurrence in a given study. For adults with pneumococcal meningitis, the reported mortality rates vary between 20 and 51% [10, 28–32]. The mortality rate is increased among patients with pneumococcal meningitis compared with those with meningococcal meningitis [10]. The mortality of meningococcal meningitis has been reported to be up to 7% for adults [33].

The higher the APACHE II, SAPS II, SOFA or GCS scores were for the group studied, the higher its mortality rate. An example of a low mortality rate associated with a low GCS value can be found in a report by Flores-Cordero *et al.* [34]. Flores-Cordero *et al.* [34] reported sixty-four episodes in 62 adults with acute community-acquired bacterial meningitis admitted to the ICU. The median GCS value was 11, and the overall mortality rate was 10.9%.

The predicted mortality rates (based on median) related to the APACHE II and SAPS scores for patients under study exceed 50%. The mortality-rate results we obtained (44.90%) are much lower but are still highly unsatisfactory.

The main limitation of the present study is its retrospective nature.

CONCLUSION

In the prediction of mortality in patients with severe purulent bacterial meningitis, the SAPS II scoring system exhibited the highest accuracy.

ACKNOWLEDGEMENTS

1. Conflict of interest — none.
2. Source of founding — none.

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Received: 5.12.2015
Accepted: 23.03.2016