A Low Dimensional Algorithm for Detection of Sepsis from Electronic Medical Record Data

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Abstract

Sepsis is an emerging potential health issue, needs to be address consciously on priority basis. Considering the importance, Physionet/Cinc announced the topic as challenge of the year 2019. Main focus of the challenge is to early detection of sepsis, as it may save life of patient, by treating in advance. The present work is a result of participation in the challenge.

Sepsis is detected by analysing the clinical parameters of the patient. Aim of this work is to study the existing methods of sepsis detection, select the parameters which can optimize the performance and to propose a new method with improved performance. With this aim, existing techniques sepsis-2 and sepsis-3 were studied and a new method was proposed to detect sepsis.

The performance of all the three methods compared in terms of accuracy, specificity, sensitivity and AUC. Results shows accuracy of 85%, specificity of 88% and sensitivity of 41% for the proposed method, while for Sepsis-2 it was, 78%,41%and 47% and in Sepsis-3 , 63%,64% and 56% in the same order of the proposed. ROC curves plotted and AUC values 0.66, 0.64 and 0.60 obtained, respectively. The study concludes that, detection of sepsis highly depends on parameter selection, weightage assigned to the parameters and criteria applied thereafter.

1. Introduction

Sepsis is defined as life threatening organ dysfunction caused by dysregulated host response to infection [1]. Onset of sepsis starts attacking functioning of body organs very fast and may cause death even with good of treatment. In spite of advances in sepsis detection technology and management tools, sepsis is one of the major cause of morbility and mortiality in critically ill patients and one of most expensive healthcare problem in United States [2,3]. Globally, 30 millions of people affected by sepsis every year, causing 6 million deaths annually [4].

Although, sepsis is very old phenomenon, an official guidelines of sepsis known as Sepsis-1, was first defined in 1991. The definition introduced Systemetic Inflammary Response (SIR) parametrs to identify the risk of sepsis. Further, the guidelines were updated in 2001, as Sepsis-2, but due lack of sufficient evidences, there were no major changes, except the addtion of suspected infection criteria [5,6]. After a long time, in 2016, a new set of guidelines were introduced as Sepsis-3, which is considered as latest one. The Sepsis-3 guidelines abandoned the SIRs and mainly focused on SOFA (Sequential-Sepsis Related-Organ Failure Assessment Score) as reference for organ dysfunction aspect [1, 7]. Sepsis- 3 also introduced a quick SOFA (qSOFA) score for primary screening of patients that might at the risk of sepsis. A detail comparison of Sepsis-2 and Sepsis-3 is discussed in a study [6]. The methods Sepsis-2 and Sepsis-3 mainly differs in the parameters selection, scores assigned to each parameter and criteria of differentiating sepsis patients from non-sepsis patients.

Though the guidelines of sepsis identification were updated, number of controversies have been reported regarding utilization of the guidelines and sepsis treatment [8]. There is still an absence of streamlined sepsis management protocols and standards which can be considered as a golden rule for the disease detection. Neither SOFA or qSOFA of Sepsis-3 is standalone definition of sepsis and at the same time the taskforce also suggested that SIR criteria of Sepsis-2 still remains useful in identification of infectious patients [1]. Thus the previous studies suggest that, to offer right therapy for right patient, biological concepts of sepsis need to be understand thoroughly[9]. So, sepsis is still a challenging topic of research and there is a wide scope for improvement in sepsis detection techniques, in general.

In this context, a new procedure, with a set of six parameters, redefined weightage and a scoring criteria is proposed in this work. The method, is a quick low dimension algorithm for binary sepsis detection. Further, results of the proposed work were compared with Sepsis-2 and Sepsis-3 algorithm implementations, to see the impact of the changes made in improving algorithm efficiency.

2. Database

Sepsis data was reffered from Physionet website, made available freely for the challenge 2019. The data is of ICU patients, from three different hospitals. The first two were provided as training set A & B respectively for testing algorithms and the third was hidden for the participants, used by organizers to score the entries. SET A consists of 20,336 and SET B ,20,000 records each. Every record has 40 parameters, out of which first 34 are clinical and remaining demographic. The parameters in each record noted hourly basis.

3. Method

This section explains the stages followed in the proposed sepsis detection algorithm by comparing it with existing Sepsis-2 and Sepsis-3 guidelines.

3.1. Generalized Procedure of Sepsis Detection

Figure 1 shows a generalized procedure of sepsis detection. It can be considered as a four stage procedure on a broad level. This is at primary level, but may further repeated for more severe conditions. Though the accurate detection of sepsis is challenging and complex procedure, the major three factors that affects sepsis detection are, clinical parameters selection, weightage assigned to the selected parameters and threshold criteria applied to differentiate between sepsis and non-sepsis patients.

Table 1 summarizes the three methods with respect to the factors mentioned. First two columns list out the parameters and its abbreviations. Thereafter, range and weightage given to each parameter for the respective methods are mentioned. The last row states the criteria used to detect sepsis.

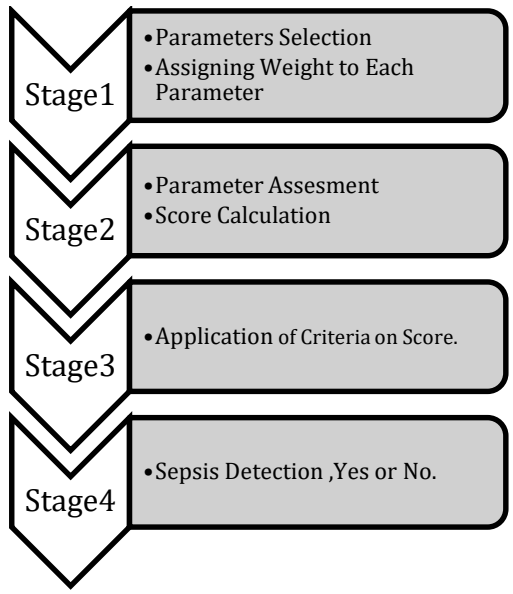

Figure 1 Generalized Sepsis Detection Procedure

Table 1 Sepsis Detection Guidelines, Weightage and Criteria, followed by the Proposed, Sepsis-2 and Sepsis-3 Methods.

Parameters		Proposed Method		Sepsis-2		Sepsis-3	
		Range	Weight	Range	Weight	Range	Weight
HR	Heart rate (beats per minute)	NA		>90	0-1	NA	
Temp	Temperature (Deg C)	NA		>38 & 36	0-1	NA	
WBC	Leukocyte count (count 10^3/µL)	NA		>12 & <4	0-1	NA	
Resp	Respiration rate (breaths per minute)	> 23	0- 0.5	>20	0-1	>22	0-1
SBP	Systolic BP (mm Hg)	>135	0-0.5	<90	0-1	>=100	0-1
MAP	Mean arterial pressure (mm Hg)	<67	0-1	NA		<67	0-1
Cr	Creatinine (mg/dL)	>2	0-1	>2	0-1	<1.2 & > 5	0-4
Bi	Bilirubin_total(mg/dL)	>2	0-1	>2	0-1	<1.2 & >12	0-4
Pt	Platelets (count*10^3/µL)	>=150 & <20	0-4	<100	0-1	>=150 & <20	0- 4
Criteria		Infection AND Total SCORE>2		Infection AND any 2 SIRS positive AND 1 SOFA points		Infection AND 2 SOFA points	

3.2. Proposed Method

3.2.1 Parameter Selection

Parameters are used to examine the patient health in sepsis detection. There can be two types of parameters, first, routine clinical measurements, called as bedside parameters and second, organ specific parameters, which are tested as and when required. The organ specific parameters are considered as critical, as they are directly link to functioning of organs and hence to sepsis detection.

Regarding the parameters selection in present work, Table 1 lists out total nine parameters. All of them may or may not applicable to each methods, if not applicable, indicated with Not Applicable (NA) label. The proposed method uses total six parameters, Resp and SBP with redefined range, MAP and Platelets with Sepsis- 3 range and Creatinine and Bilirubin with Sepsis-2 ranges. Selection and finalization of the parameters and the ranges was done by experimenting and comparing results of different combination of parameters and ranges. While, Sepsis-2 uses total eight parameters, HR, Temp, Resp and WBC known as SIRs and Cr, Bi, Pt and SBP as SOFA parameters, with ranges indicated as in Table 1. And, Sepsis-3 guidelines makes use of total six parameters, Resp and SBP as quick SOFA (qSOFA) and Cr, Bi, Pt and MAP as SOFA scorer. Thus, every method has a combination of routine and organ specific measures and highest number of parameters used by Sepsis-2 method.

3.2.2 Assigning Weightage to each Parameter

After selection, every parameter is assigned a weightage, called as points sometimes. The Sepsis-3 guidelines had broaden the weightage of SOFA parameters, on 0-4 scale while qSOFA parameters are defined on 0-1 scale. Sepsis-2 has similar weightage to all parameters, which is on 0-1 scale. The proposed method assigns lesser weight to clinical parameters, Resp and SBP, 0-0.5 scale and higher to SOFA parameters, 0-1 scale.

3.2.3 Sepsis Detection

The parameters were asses by each method and final score was calculated by summing up weightages. Finally, sepsis detection is done by applying predefined threshold criteria, on the score, as stated in last row of Table 1, of respective methods. The proposed method has a single and simple scoring calculation, while sepsis-2 uses two stage criteria.

3.3. Evaluation Parameters

Evaluation parameters used to analyze the results are, Sensitivity, Specificity and Accuracy**.** ROC curves were plotted and area under curve (AUC) was calculated for each method.

4. Results

Results of 500 subjects, from training set A of the challenge dataset are presented here. Each subject has hourly recorded data of forty different parameters. Number of hours are different in each record. The sepsis detection was performed for every hour of the data. If detected at any one or more instances, then sepsis is considered as positive, otherwise negative. Validation of algorithm is performed by comparing the results from the algorithm with actual detection available in the dataset.

Table 2 summarizes the performance of the three methods in terms of accuracy, specificity, sensitivity and AUC. Figure 2 depict ROC curves for each method.

Table 2 Performance Evaluation Parameters.

	Proposed Method	Sepsis-2	Sepsis-3
Accuracy	85	78	63
Specificity	88	81	64
Sensitivity	41	47	56
AUC	0.66	0.64	0.60

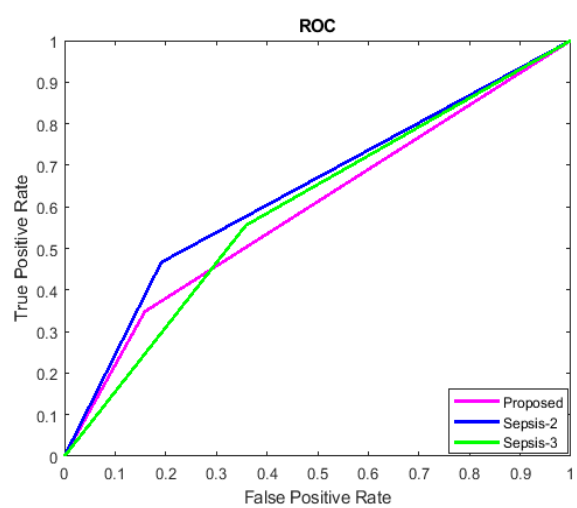

Figure 2. ROC curves of the Three Methods.

5. Discussion

Figure 3 shows a performance comparison of the three methods in terms of accuracy, specificity and sensitivity.

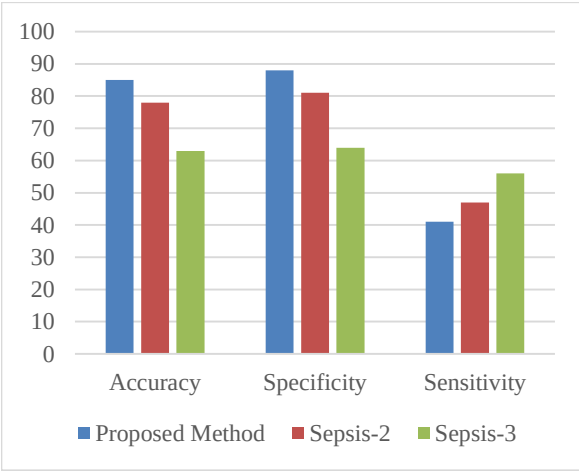

Figure 3. Comparison of Performance

Accuracy indicates ability of correct detection. The proposed method gave accuracy of 85%, highest, compare to other two. Specificity, which is ability to detect true negative or no sepsis patients, is again highest in proposed method, 88% and lower in Sepsis-2 and Sepsis-3. The improvement was due to redefined parameter criteria. Sensitivity, a measure of true positive detection or positive sepsis is overall low in all of the methods and comparatively highest in Sepsis-3 method. This may be probably due to, Sepsis-3 concentrates on SOFA parameters. Previous studies also support this observation, in emergency ward, for critically ill patients the Sepsis-3 method gives superior performance than Sepsis-2 [7]. The proposed method need to improve for positive detection that is sensitivity, which needs further investigation and experimentation. Thus, the main finding of this study was that, accuracy of sepsis detection was improved with optimum number of parameters and assigning appropriate weightage to each, in a simple way, without using any highly sophisticated algorithm.

Present study is limited to binary detection of sepsis, which is yes or no detection. Severe sepsis and septic shock are not yet covered in the algorithm. Sepsis is a complicated phenomenon which is affected by age, gender, and type of illness, antibiotics treatment, vitamin and many more. So further in depth study is future ongoing work. Early detection of sepsis is another important aspect as it may save life by giving fast and necessary treatment to patients in advance. The work is in progress in this regard.

6. Conclusion

In this study, a new sepsis detection method was proposed and implemented with a redefined set of parameters and with a new scoring criteria. The accuracy and specificity of sepsis detection was improved. So it can be concluded that right selection of parameters and its weightage plays an important role in identification of sepsis patients. At the same time, sepsis detection remains challenging topic because it is a complex phenomenon to understand and treat.

References

[1] Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). JAMA ;315:801-10,2016.

[2] Kaukonen K, Bailey M, Suzuki S, et al. Mortality related to severe sepsis and septic shock among critically Ill patients in Australia and New Zealand, 2000–2012. JAMA; 311(13):1308–1316,2014.

[3]Torio CM and Andrews RM. National inpatient hospital costs:the most expensive conditions by payer, 2011. Statistical Brief #160. August, 2013.

[4] Bishal Gyawali, Karan Ramakrishna, Amit S Dhamoon," Sepsis: The evolution in definition,pathophysiology, and management ", SAGE Open Medicine,, Volume 7: 1–13,2019.

[5] Marik PE, Taeb AM. SIRS, qSOFA and new sepsis definition. Journal of Thorac Disease 9(4):943-945, doi: 10.21037/jtd.2017.03.125,2017.

[6] M. Shankar-Hari, D. A. Harrison, G. D. Rubenfeld and K. Rowan," Epidemiology of sepsis and septic shock in critical care units: comparison between sepsis-2 and sepsis-3 populations using a national critical care database", British Journal of Anaesthesia, 119 (4): 626–36,2017.

[7]Charitos, Topi, Castellaneta et al" Current Issues and Perspectives in Patients with Possible Sepsis at Emergency Departments", Antibiotics 8, 56;2019.

[8]Williams JM, Greenslade JH, McKenzie JV, et al. SIRS, qSOFA and organ dysfunction: insights from a prospective database of emergency department patients with infection. Chest;151:586-596,2017.

[9]Jack Varon and Rebecca M. Baron," A current appraisal of evidence for the approach to sepsis and septic shock", Therapeutic Advances in Infectious Disease, Vol. 6: 1–14, 2019.

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