phoenix: R package and Python module for calculating the Phoenix Pediatric Sepsis Score and Criteria

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# Abstract

words: 145/150 words

**Objectives**

The publication of the Phoenix criteria for pediatric sepsis and septic shock initiates a new era in clinical care and research of pediatric sepsis. Tools to consistently and accurately apply the Phoenix criteria to electronic health records (EHRs) is one part of building a robust and internally consistent body of research across multiple research groups and data sets.

**Materials and Methods**

We developed the phoenix R package and Python module to provide researchers with intuitive and simple functions to apply the Phoenix criteria to EHR data.

**Results**

The phoenix R package and Python module enable researchers to apply the Phoenix criteria to EHR datasets and derive the relevant indicators, total scores, and sub-scores.

**Conclusions**

The phoenix R package and Python model are freely available on CRAN and PyPi, respectively. These tools enable the consistent and accurate application of the Phoenix criteria to EHR datasets.

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| Table 1: The Organ Dysfunction Scoring for the Phoenix Criteria. The Phoenix sepsis criteria are based on the Phoenix Sepsis Score, which includes respiratory, cardiovascular, coagulation, and neurologic dysfunction; Phoenix-8 is based on those four organ systems plus endocrine, immunologic, renal, and hepatic dysfunction. Sepsis is defined as a Phoenix Sepsis Score ≥ 2. Septic Shock is defined as sepsis with at least one cardiovascular point. The limits reported in this table reflect the implementation of the criteria in software, whereas the comparable published tables report the criteria from a clinical perspective.[3,4] The two representations of the criteria are consistent in practice.   | Organ System | 0 Points | 1 Point | 2 Points | 3 Points | | --- | --- | --- | --- | --- | | **Respiratory** (0-3 points) |  |  |  |  | |  |  | Any respiratory support | IMV[[1]](#footnote-1) | IMV | | PaO2:FiO2 | ≥ 400 | < 400 | < 200 | < 100 | | SpO2:FiO2[[2]](#footnote-2) | ≥ 292 | < 292 | < 220 | < 148 | | **Cardiovascular** (0-6 points; sum of medications, Lactate, and MAP) |  |  |  |  | | System Vasoactive Medications[[3]](#footnote-3) | No medications | 1 medication | 2 or more medications |  | | Lactate[[4]](#footnote-4) (mmol/L) | < 5 | 5 ≤ Lactate[[5]](#footnote-5) < 11 | ≥ 11 |  | | Age[[6]](#footnote-6) (months) adjusted MAP[[7]](#footnote-7) (mmHg) |  |  |  |  | | 0 ≤ Age < 1 | ≥ 31 | 17 ≤ MAP < 31 | < 17 |  | | 1 ≤ Age < 12 | ≥ 39 | 25 ≤ MAP < 39 | < 25 |  | | 12 ≤ Age < 24 | ≥ 44 | 31 ≤ MAP < 44 | < 31 |  | | 24 ≤ Age < 60 | ≥ 45 | 32 ≤ MAP < 45 | < 32 |  | | 60 ≤ Age < 144 | ≥ 49 | 36 ≤ MAP < 49 | < 36 |  | | 144 ≤ Age < 216 | ≥ 52 | 38 ≤ MAP < 52 | < 38 |  | | **Coagulation**[[8]](#footnote-8) (0-2 points; 1 for each lab; max of 2 points) |  |  |  |  | | Platelets (1000/μL) | ≥ 100 | < 100 |  |  | | INR | ≤ 1.3 | > 1.3 |  |  | | D-Dimer (mg/L FEU) | ≤ 2 | > 2 |  |  | | Fibrinogen (mg/dL) | ≥ 100 | < 100 |  |  | | **Neurologic**[[9]](#footnote-9) (0-2 points) |  |  |  |  | |  | GCS[[10]](#footnote-10) ≥ 11 | GCS ≤ 10 | Bilaterally fixed pupils |  | | **Endocrine** (0-1 point) |  |  |  |  | | Blood Glucose (mg/dL) | 50 ≤ Blood Glucose ≤ 150 | < 50; or > 150 |  |  | | **Immunologic** (0-1 point; point from ANC and/or ALC) |  |  |  |  | | ANC (cells/mm[^3]) | ≥ 500 | < 500 |  |  | | ALC (cells/mm[^3]) | ≥ 1000 | < 1000 |  |  | | **Renal** (0-1 point) |  |  |  |  | | Age[[11]](#footnote-11) (months) adjusted Creatinine (mg/dL) |  |  |  |  | | 0 ≤ Age < 1 | < 0.8 | ≥ 0.8 |  |  | | 1 ≤ Age < 12 | < 0.3 | ≥ 0.3 |  |  | | 12 ≤ Age < 24 | < 0.4 | ≥ 0.4 |  |  | | 24 ≤ Age < 60 | < 0.6 | ≥ 0.6 |  |  | | 60 ≤ Age < 144 | < 0.7 | ≥ 0.7 |  |  | | 144 ≤ Age < 216 | < 1.0 | ≥ 1.0 |  |  | | **Hepatic** (0-1 point; point from total bilirubin and/or ALT) |  |  |  |  | | Total Bilirubin (mg/dL) | < 4 | ≥ 4 |  |  | | ALT (IU/L) | ≤ 102 | > 102 |  |  | |

library(phoenix)  
dim(sepsis)  
## [1] 20 27  
names(sepsis)  
## [1] "pid" "age" "fio2" "pao2"   
## [5] "spo2" "vent" "gcs\_total" "pupil"   
## [9] "platelets" "inr" "d\_dimer" "fibrinogen"   
## [13] "dbp" "sbp" "lactate" "dobutamine"   
## [17] "dopamine" "epinephrine" "milrinone" "norepinephrine"  
## [21] "vasopressin" "glucose" "anc" "alc"   
## [25] "creatinine" "bilirubin" "alt"

# References

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1. Abbreviations: ALC: Absolute lymphocyte count; ALT: alanine aminotransferase; ANC: Absolute neutrophil count; FEU: fibrinogen equivalent units; FiO2: fraction of inspired oxygen; GCS: Glasgow Coma Score; IMV: invasive mechanical ventilation; INR: International normalized ratio; MAP: mean arterial pressure; PaO2: arterial oxygen pressure; SpO2: pulse oximetry oxygen saturation; [↑](#footnote-ref-1)
2. SpO2:FiO2 is only valid when SpO2 ≤ 97. [↑](#footnote-ref-2)
3. Vasoactive medications: any systemic dose of dobutamine, dopamine, epinephrine, milrinone, norepinephrine, and/or vasopressin. [↑](#footnote-ref-3)
4. Lactate can be arterial or venous. Reference range 0.5 - 2.2 mmol/L [↑](#footnote-ref-4)
5. The verbosity of this table is greater than in the tables in the original source publications.[3,4] The inequalities reported in this table, and the specific values reported in this table, reflect how the criteria is implemented in software whereas the source publications reported tables consistent with clinical practice. A couple notable differences. 1 cardiovascular point is reached for a lactate value of “5-10.9 mmol/L” and 2 points for lactate ≥ 11 mmol/L.[3,4] There is an implication of rounding lactate to one decimal place and assessing the criteria. The software simplifies the work by considering lactate values to be a floating point value that could take on any real value and thus the logic of “5 ≤ lactate < 11” for 1 point. Additionally, for MAP, the criteria listed in this table is consistent with common clinical practice of interpreting MAP as integer values. The criteria listed in this table is used with the assumption that MAP values are floating point values. [↑](#footnote-ref-5)
6. Age: measured in months and is not adjusted for prematurity. [↑](#footnote-ref-6)
7. MAP - Use measured mean arterial pressure preferentially (invasive arterial if available, or non-invasive oscillometric), alternatively use the calculation diastolic + (systolic - diastolic) / 3 [↑](#footnote-ref-7)
8. Coagulation variable reference ranges: platelets, 150-450 103/μL; D-dimer, < 0.5 mg/L FEU; fibrinogen, 180-410 mg/dL. International normalized ratio reference range is based on local reference prothrombin time. [↑](#footnote-ref-8)
9. Neurologic dysfunction scoring was pragmatically validated in both sedated and on sedated patients and those with and without IMV. [↑](#footnote-ref-9)
10. GCS measures level of consciousness based on verbal, eye, and motor response. Values are integers from 3 to 15 with higher scores indicating better neurologic function. [↑](#footnote-ref-10)
11. Age: measured in months and is not adjusted for prematurity. [↑](#footnote-ref-11)