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EAVA: An R package for Expert Algorithm Verbal Autopsy (EAVA) cause of death assignment

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Summary

EAVA (Expert Algorithm Verbal Autopsy) is an R package for determining cause of death (COD) using verbal autopsy (VA) interview questionnaire data, a predominant tool to determine cause of death in under-resourced settings (Nichols et al., 2018). The EAVA R package translates the methodology created and validated by Kalter and colleagues (Kalter et al., 2016) to diagnose a cause of death from VA records of neonates and children (1 to 59 months of age). EAVA inputs data from the 2016 version of the WHO Verbal Autopsy (VA) questionnaire and outputs a cause of death (COD) for each VA record based on a deterministic hierarchy of causes. The assignment approach utilizes the decedent's age to decide which of two separate hierarchies will determine a cause of death.

Statement of need

Most deaths occur outside of a medical setting and as a result, the causes of these deaths are not captured. Verbal autopsies conducted in the community, usually at the homes of children who died, are used to understand the most common causes of death in settings where civil registration systems need to be strengthened (WHO, 2016). Physicians assess signs and symptoms, which were reported to be present at the time of death by a decedent's caregiver during the Verbal Autopsy, and assign a cause of death deemed most likely. To account for bias, physician-coded verbal autopsy (PCVA) requires that verbal autopsy questionnaire data are read by multiple physicians. PCVA is time-intensive for physicians in resource-limited settings and repeatability can be low in childhood deaths (Chandramohan et al., 1998).

Over the last decade, there has been increased adoption of algorithmic cause-ascertainment from VA. These algorithms, termed as Computer-Coded Verbal Autopsy (CCVA), are considerably less time- and resource-intensive than PCVA, facilitating scalability of obtaining COD for large (national- or sub-national-level) VA databases. There now exists a suite of CCVA algorithms for COD ascertainment from VA data – EAVA, InterVA4, InterVA5, InSilicoVA, Tariff, and Naïve Bayes Classifier (Li et al., 2022). Each algorithm differs in implementation details and underlying methodology. However, except EAVA, most of these are primarily data-driven, estimating some form of a conditional probability symptom-given-cause matrix. These estimates are primarily derived from the Population Health Metrics Research Consortium (PHMRC) study, conducted in 2011, which contains both VA records and validated 'gold-standard' causes (Murray et al., 2011). Reliance on PHMRC limits generalizability in newer VA studies. It has been shown that most CCVA algorithms misclassify the cause for a substantial proportion of deaths (Datta et al., 2021; Fiksel et al., 2022).

EAVA addresses some of the drawbacks of physician coding and is not reliant on PHMRC data. It automates and replicates the decision trees of human physician coders as it assesses signs and symptoms of common causes of death, arriving at a single diagnosis using ICD-10 classifications in the hierarchy. If diagnostic criteria are not met for any cause, the neonate or 1-to-59-month-old child is assigned a COD of "unspecified" (Appendices 1 and 2). EAVA has been shown to yield comparable accuracy to the other CCVA algorithms (Fiksel et al., 2023; Gilbert et al., 2023). The COD outputs from EAVA can also be used in the VA calibration algorithm which combines COD ascertainment from multiple CCVA algorithms and adjusts for their biases to produce a calibrated estimate of population-level cause-specific mortality fractions (Datta et al., 2021; Fiksel et al., 2022; Pramanik et al., 2023). Inclusion of CCVA algorithms with different cause-ascertainment logic ensures robustness of results for VA calibration. Hence, due to the fundamentally different decision-making nature of EAVA compared to other CCVA algorithms, it is now a central component of the VA calibration algorithm and has been used in VA-calibration to produce bias-corrected estimates of CSMF for child (1-59 months) and neonatal deaths in Mozambique (Fiksel et al., 2023; Gilbert et al., 2023; Macicame et al., 2023)

The EAVA R package takes EAVA analytical scripts originally compiled in SAS and R and makes the methodology publicly available in CRAN, which expands the potential for research use, ongoing development, and future integration into VA pipelines and toolkits.

State of the field

Many of the aforementioned CCVA algorithms (EAVA, InterVA4, InterVA5, InSilicoVA, Tariff, and Naïve Bayes Classifier) are implemented in the openVA R package (Zehang et al., 2024). The CrossVA package converts 2016 WHO VA questionnaire data to a standard input format for use in openVA (Thomas et al., 2021). There is also standalone software for some CCVA algorithms, for example, the InterVA algorithm (Byass, 2020) and the SmartVA algorithm (Flaxman, 2025). There has been no publicly available version of EAVA prior to this R package.

The EAVA package

The EAVA R package comprises two functions (Wilson et al., 2025). The first function is odk2EAVA which builds on the CrossVA package to convert interview responses from the 2016 WHO Verbal Autopsy questionnaire into standardized inputs for use in codEAVA. The second function, codEAVA, evaluates whether reported symptoms meet diagnostic criteria of common causes of death and assigns a main cause based on a hierarchy of causes. The algorithm utilizes age-group specific ascertainment logic due to significant differences between the common causes of death of neonates 0-27 days (Appendix 1) and children aged 1-to-59-months (Appendix 2).

Acknowledgements

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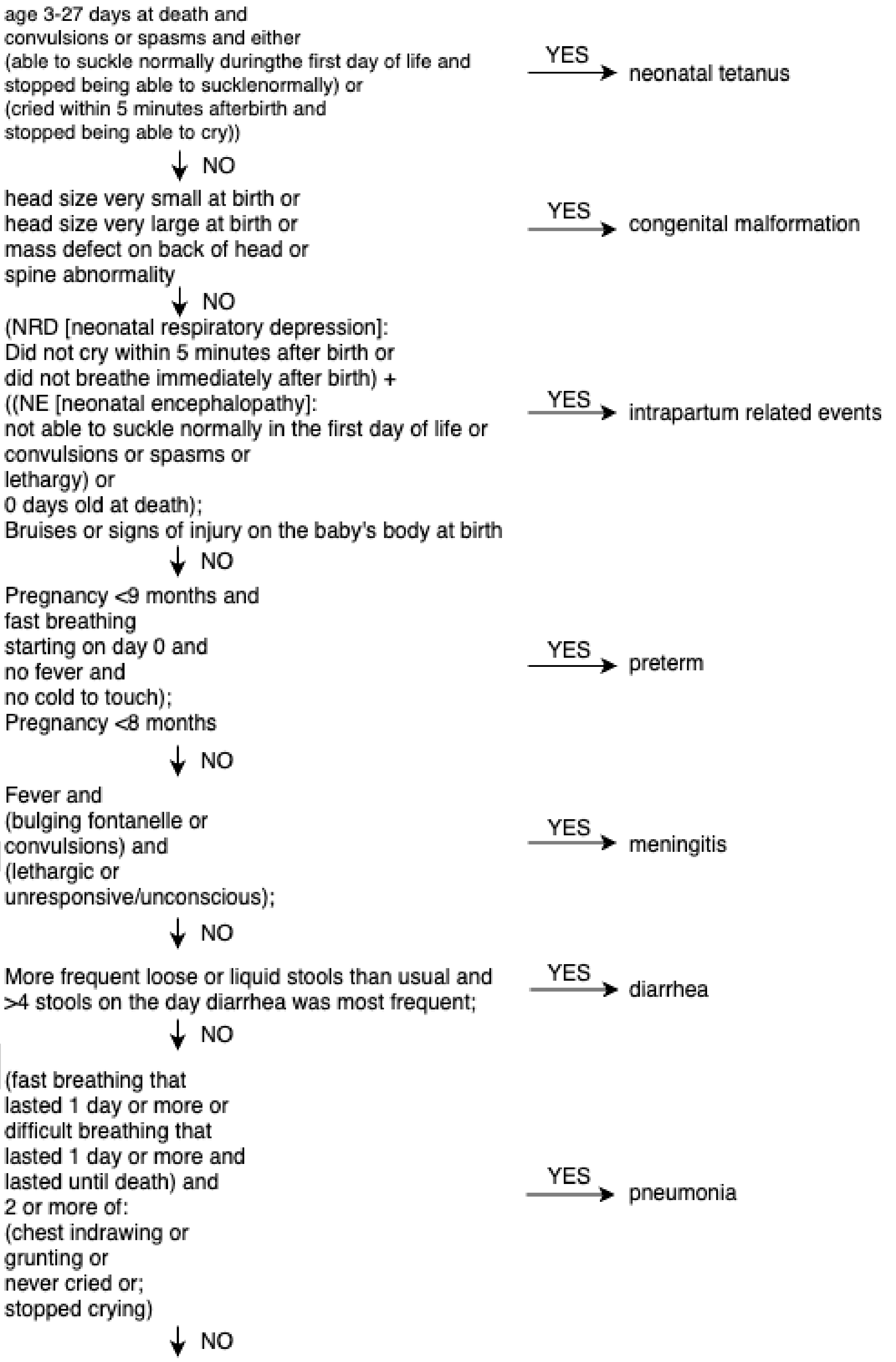
Appendix 1: deterministic hierarchical algorithm to reach a single cause of death in neonates



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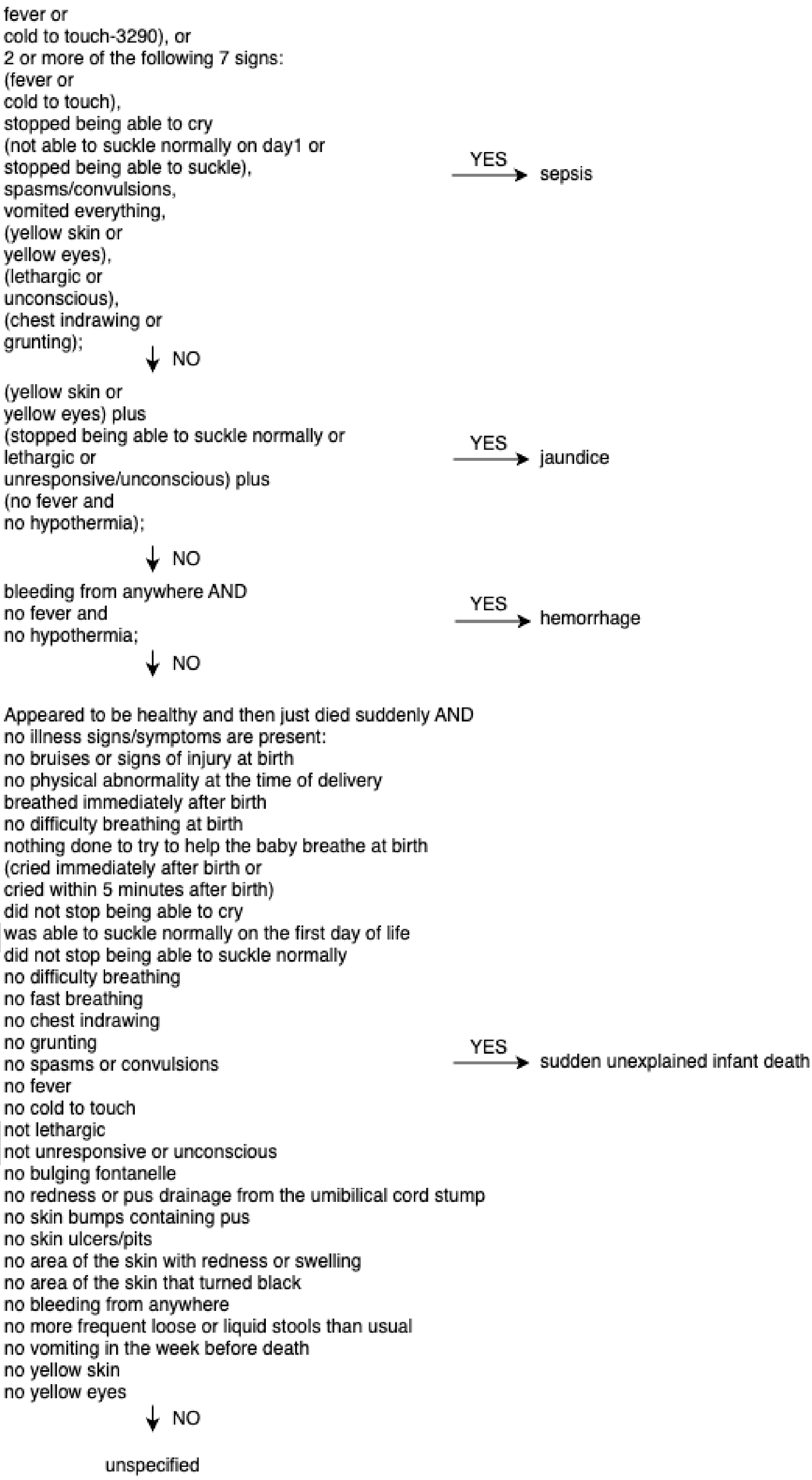

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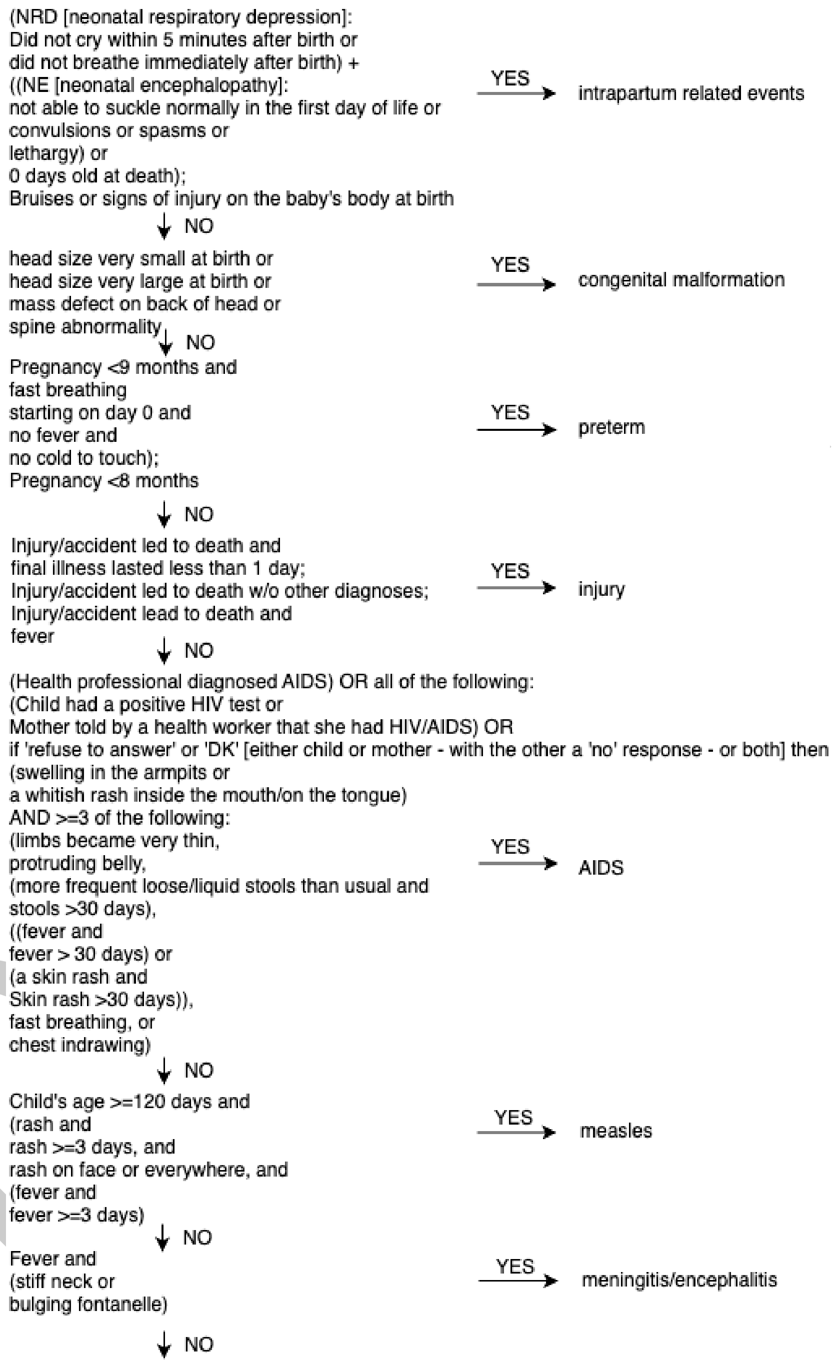
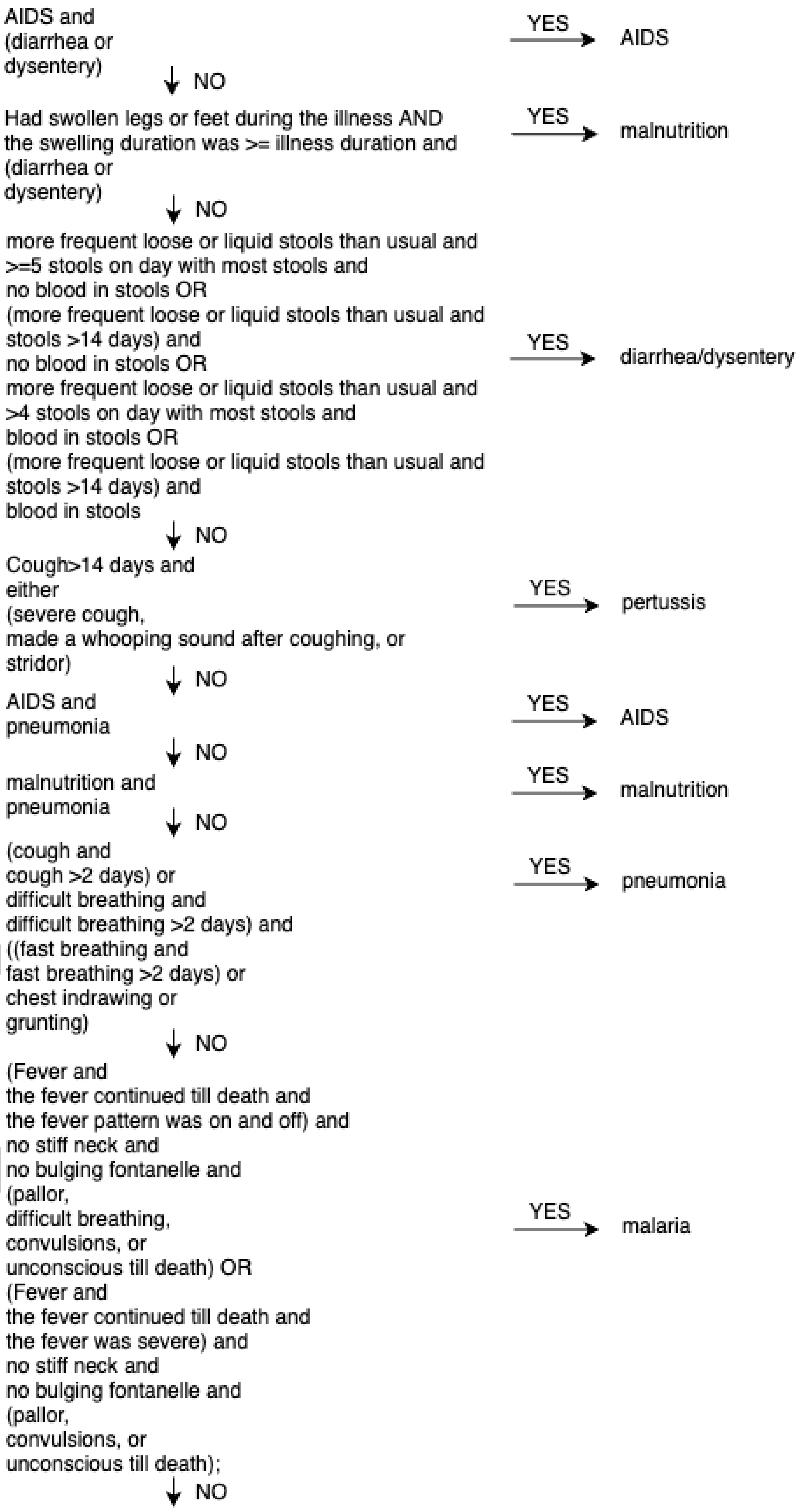
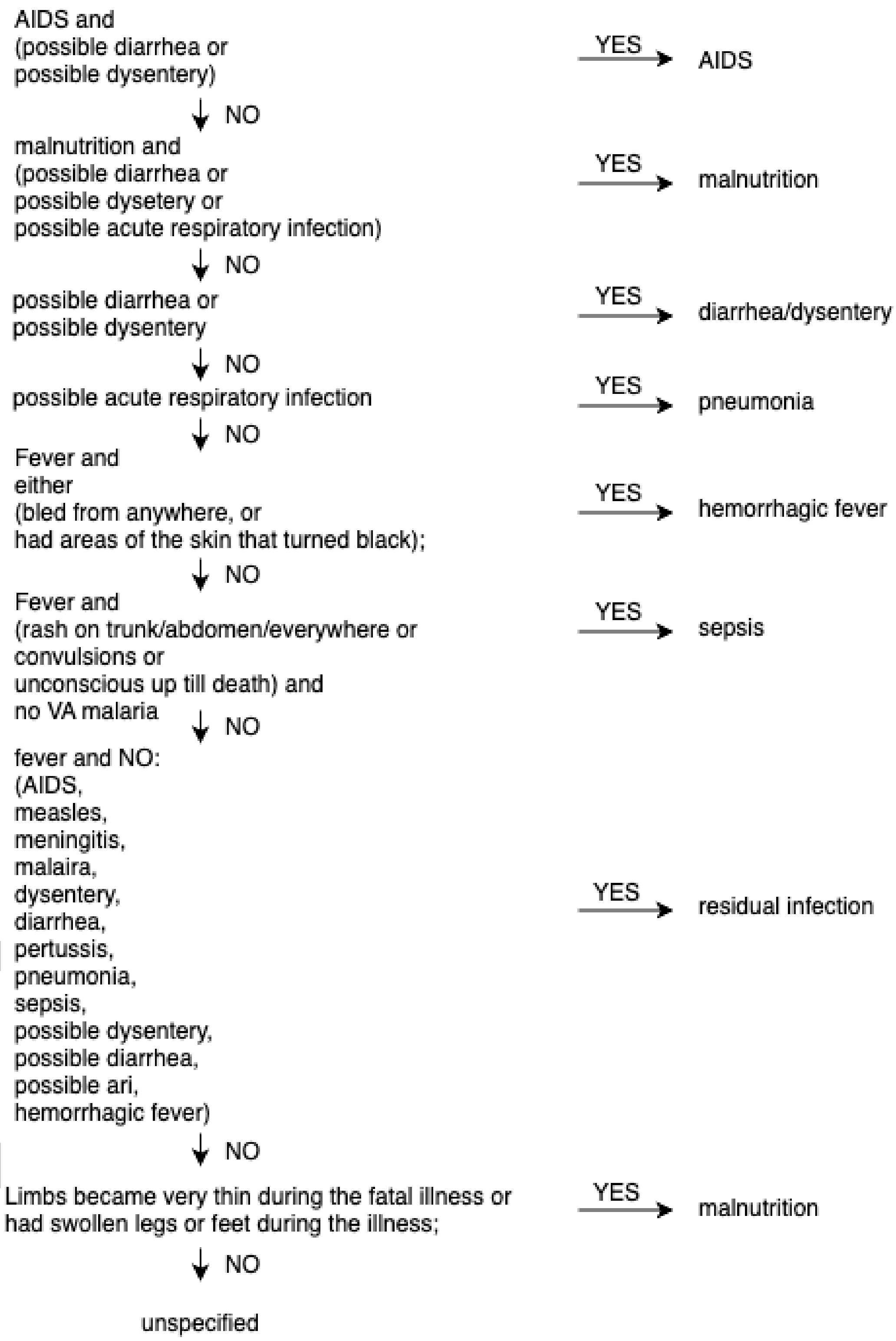
Appendix 2: deterministic hierarchical algorithm to reach a single cause of death in children 1-to-59-months-of-age




AIDS and
(diarrhea or
dysentery)
YES
AIDS
NO
Had swollen legs or feet during the illness AND
the swelling duration was >= illness duration and
(diarrhea or
dysentery)
YES
malnutrition
NO
more frequent loose or liquid stools than usual and
>=5 stools on day with most stools and
no blood in stools OR
(more frequent loose or liquid stools than usual and
stools >14 days) and
no blood in stools OR
more frequent loose or liquid stools than usual and
>4 stools on day with most stools and
blood in stools OR
(more frequent loose or liquid stools than usual and
stools >14 days) and
blood in stools
YES
diarrhea/dysentery
NO
Cough>14 days and
either
(severe cough,
made a whooping sound after coughing, or
stridor)
YES
pertussis
NO
AIDS and
pneumonia
YES
AIDS
NO
malnutrition and
pneumonia
YES
malnutrition
NO
(cough and
cough >2 days) or
difficult breathing and
difficult breathing >2 days) and
((fast breathing and
fast breathing >2 days) or
chest indrawing or
grunting)
YES
pneumonia
NO
(Fever and
the fever continued till death and
the fever pattern was on and off) and
no stiff neck and
no bulging fontanelle and
(pallor,
difficult breathing,
convulsions, or
unconscious till death) OR
(Fever and
the fever continued till death and
the fever was severe) and
no stiff neck and
no bulging fontanelle and
(pallor,
convulsions, or
unconscious till death);
YES
malaria
NO


AIDS and
(possible diarrhea or
possible dysentery)
YES
AIDS
NO
malnutrition and
(possible diarrhea or
possible dysetery or
possible acute respiratory infection)
YES
malnutrition
NO
possible diarrhea or
possible dysentery
YES
diarrhea/dysentery
NO
possible acute respiratory infection
YES
pneumonia
NO
Fever and
either
(bled from anywhere, or
had areas of the skin that turned black);
YES
hemorrhagic fever
NO
Fever and
(rash on trunk/abdomen/everywhere or
convulsions or
unconscious up till death) and
no VA malaria
YES
sepsis
NO
fever and NO:
(AIDS,
measles,
meningitis,
malaira,
dysentery,
diarrhea,
pertussis,
pneumonia,
sepsis,
possible dysentery,
possible diarrhea,
possible ari,
hemorrhagic fever)
YES
residual infection
NO
Limbs became very thin during the fatal illness or
had swollen legs or feet during the illness;
YES
malnutrition
NO
unspecified

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