Bayes EM – Real Time Bayesian Analysis at the Bedside

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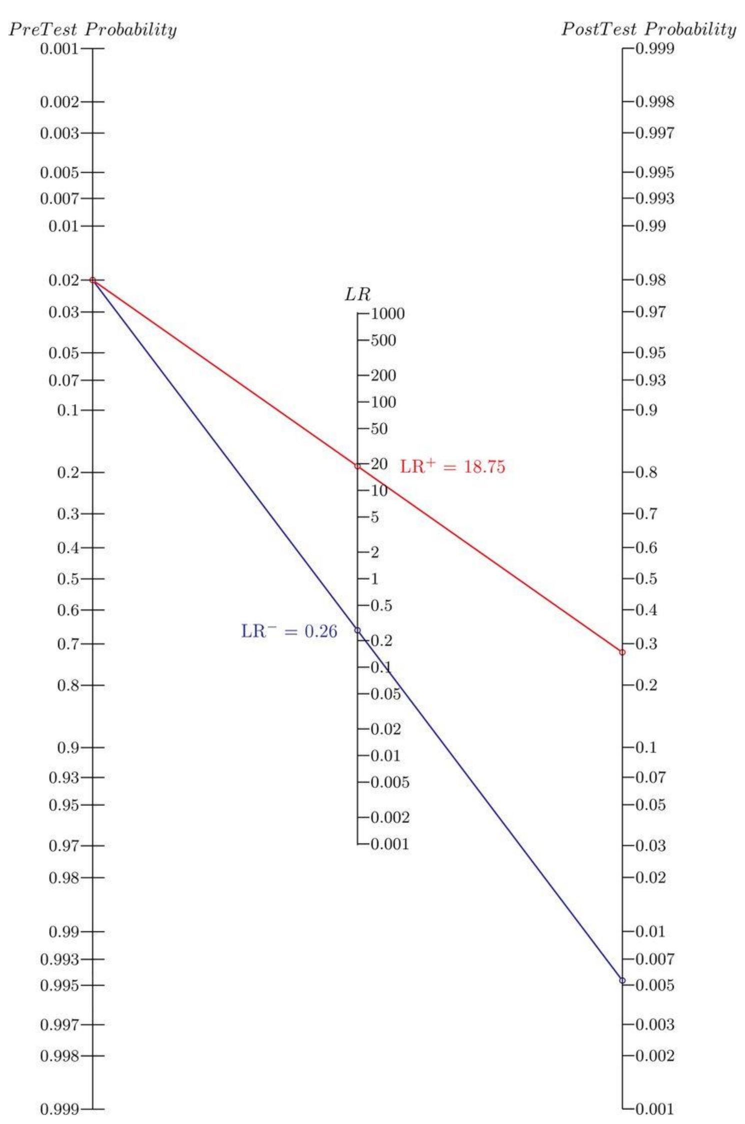
Introduction

Clinical decision making, or diagnostic reasoning, is perhaps the most critical skill that physicians possess[1]. This skill is particularly salient to the field of emergency medicine, a specialty which is marked by high diagnostic uncertainty and high decision-density, in a practice environment which is often chaotic and unpredictable[2]. Unfortunately, most medical school and residency curricula lack formal teaching of diagnostic reasoning[1]. Learners are generally expected to acquire their skills in clinical decision making by "osmosis, example, mentorship, mimicry, or by other means"[3]– also known as the "apprenticeship model" of learning diagnostic reasoning[2]. With the lack of directed education in diagnostic reasoning during medical training, it is not surprising that studies have shown than an "inflection point" in the accuracy of clinical reasoning does not occur until sometime after graduation from EM residency[4]

One potentially effective educational tool to bridge the knowledge of experienced clinicians with the cognition of learners is the use of Bayesian analytics in the clinical environment. By centering a diagnostic question in the concepts of pre- and post-test probabilities, likelihood ratios, and testing/treatment thresholds, the implicit/heuristic thought process of an expert can be made explicit and taught to the learners. As an example, an expert clinician will know from experience that the absence of fever does not rule out pneumonia in an immunosuppressed, elderly patient with a productive cough and shortness of breath. A learner, who lacks such experience, may erroneously rule-out pneumonia in this patient based on lack of a fever, thereby making a diagnostic error. If there were a way for real time, brief, Bayesian evaluation (ie, what is the negative likelihood ratio for fever in geriatric pneumonia, and how does this affect my diagnostic approach given my pretest probability of pneumonia in this patient?), there would be ample opportunity for explicit sharing of the expert's implicit knowledge[2].

In practice, Bayesian probability in medicine is taught sparingly. An ideal way to teach Bayesian clinical decision making would be to incorporate it into the current "apprenticeship" model of clinical bedside education. One-off lectures that present theoretical applications of Bayesian analysis may be limited by lack of applicability, practicality and retention. Smartphone-based apps provide an ideal tool for this learning due to the ubiquity of smartphones and practicality of use in real-time. Our work in creating this application is to make easy the most difficult aspects of performing Bayesian analysis, namely the literature search to obtain likelihood ratios, and making the mathematical calculations of Bayes theorem[5].

Methodology

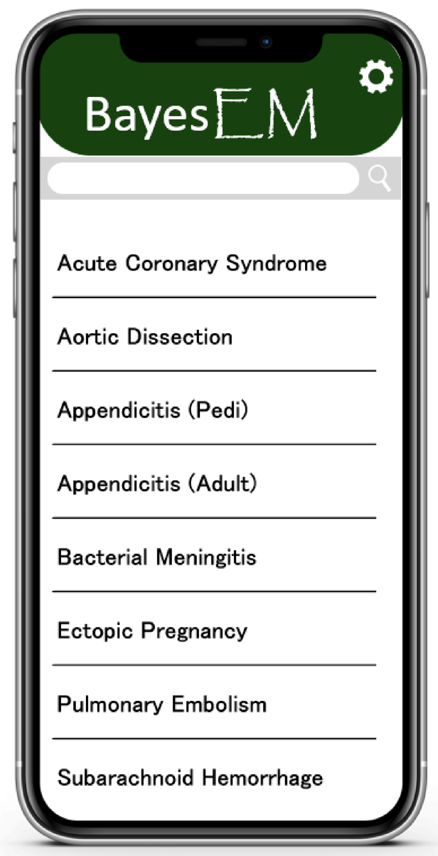


The Bayesian algorithm multiples a pretest probability with each likelihood ratio of a given symptom/sign/lab test to output a post-test probability. Each pretest probability is based on the prevalence of a condition based in the literature. Likelihood ratios were calculated through a meta analysis of all available literature. When given, likelihood ratios were aggregated across sources according to the n value of each study. Otherwise, likelihood ratios were calculated through the sensitivity and specificity of a given symptom/sign/lab test

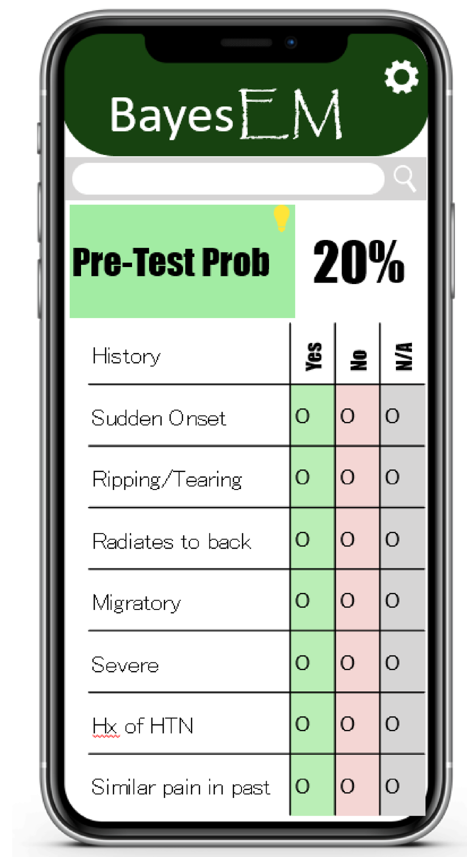
$$\textit{Positive likelihood ratio } (+LR) = \frac{sensitivity}{1 - specificity}$$

$$\textit{Negative likelihood ratio } (+LR) = \frac{1 - sensitivity}{specificity}$$

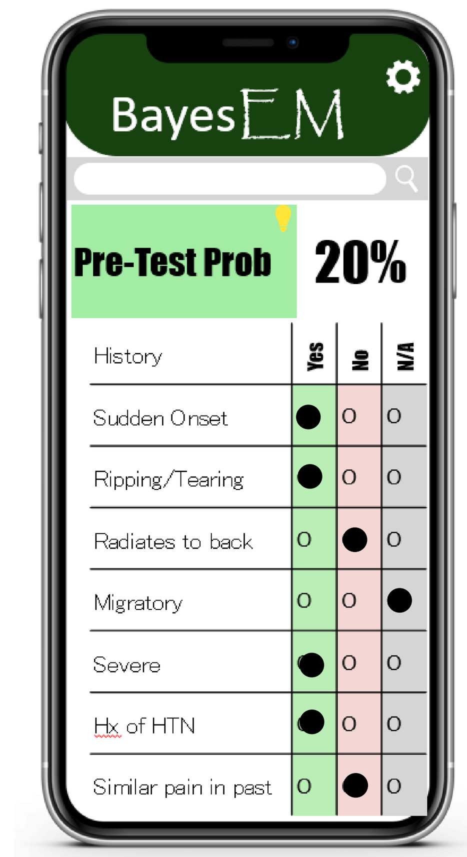
Application/Results



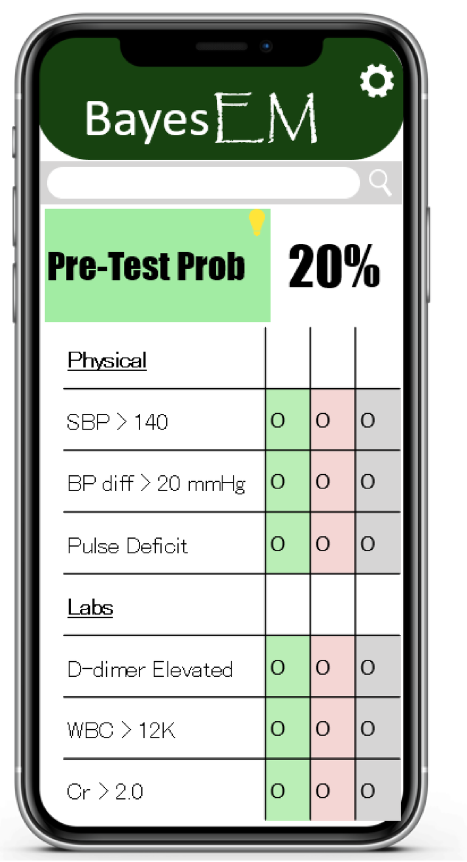
1 - Users will select one or more of ~80 emergency conditions for which the best available medical literature has been searched for test characteristics



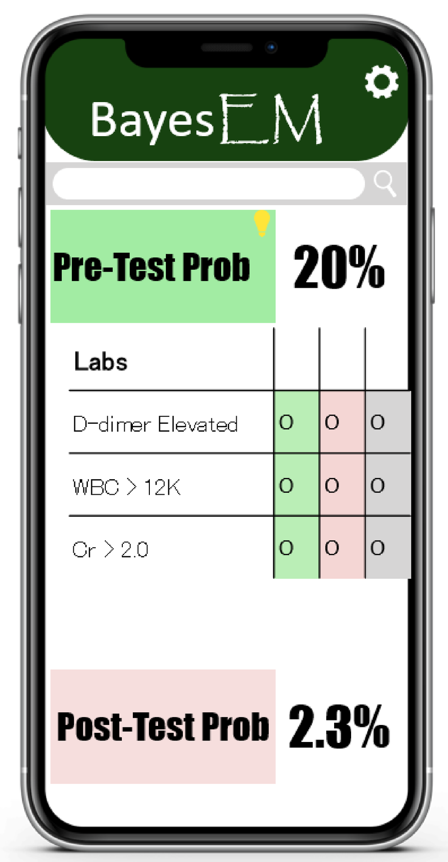
2 – Given the condition, a pre-test probability will be given that reflects the prevalence of the condition based on best available medical literature



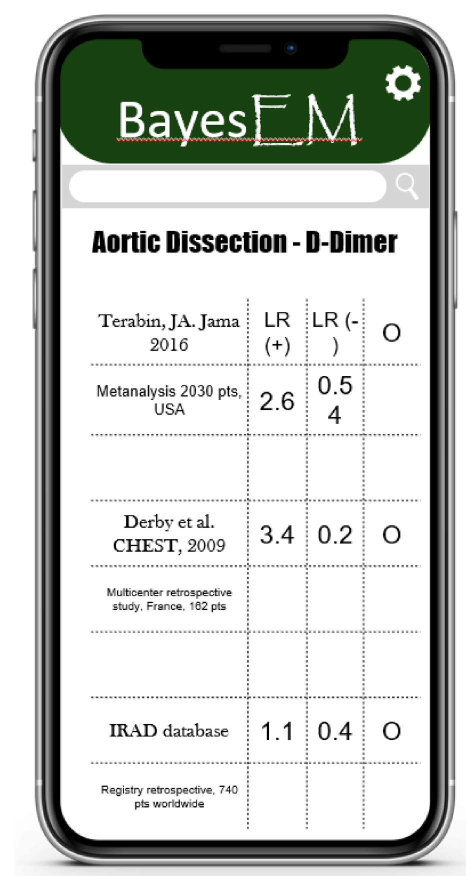
3 – Users will then input the presence/absence of specific signs and symptoms associated with the condition



4 – Physical exam findings and diagnostic tests can also be input



5 – The app will show real-time changes in post-test probability as each factor is input using Bayesian analysis based upon likelihood ratios, sensitivities, and specificities found in the literature



6 – There will be embedded references for each topic as well that can be clicked on to link to the underlying literature

Acknowledgements and References

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References

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