Engineering CDC Immunization Forecasting Rules

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Introduction and Background

Each year, the CDC publishes immunization schedules for children/adolescents and adults. A study performed in 2012[1] evaluated the effectiveness of childhood immunization guidelines implemented in the Regenstrief EHR. It compared pediatric vaccination suggestions by nurses against the CDC. The survey reported that nursing suggestions diverged from the guidelines due to the following: 1) vaccination eligibility was missed by nurses 2) nurses sometimes suggested a vaccination before the recommended minimum age or minimum dose administration interval 3) lack of validation of immunization history by nurses 4) patients were administered an extra dose. This study highlights the need for automatic vaccine evaluation and administration forecasting within an EHR at the point of care.

Method

As depicted in Figure 1, our approach is to first identify the conditions under which a vaccine is not indicated. If none of the "not indicated" forecasting scenarios apply, then the vaccine is indicated. Determination on whether a patient is not indicated for a certain vaccine should be based on: (a) any contraindication to vaccine administration, (b) the allowed timeframe for vaccine administration, and (c) vaccine series completion. Contraindications for a given vaccine should be determined by available medical history, including current immunity to the disease, medical conditions defined as contraindications, or adverse reactions to previous administrations. The timeframe is established based on the minimum and maximum age ranges suggested in the guidelines. We also allow for the incorporation of "catch-up" vaccine regimens by implementing an absolute maximum age limit for appropriate vaccine series. Lastly, patients will not be indicated for a vaccine if they have already completed the vaccine series according to CDC guidelines.

Results

If the evaluation of patient data does not result in a vaccine administration being "not indicated", then, by process of elimination, the patient falls under an indication scenario. The determination of which dose in the series a patient qualifies for is based on current age, history of previous administrations, and any high-risk conditions to begin a vaccine series which would not be indicated otherwise. Some scenarios also need to be qualified with a precaution when specific conditions are present. Providers are asked to use clinical judgment to determine future vaccine administrations whenever patient data falls outside of the published guidelines for "indicated" or "not indicated",. We applied this process and recently completed the authoring of all CDC immunization schedule rules. The rules are currently being tested and validated.

Discussion

Our aim at Partners Healthcare is to interpret the CDC immunization guidelines [2] and create executable rules to represent the suggested vaccination schedule and the catch up schedule. We applied a systematic knowledge engineering process for immunization schedule decision support rules. The process includes: (1) Extraction and modeling of the patient data elements referenced in the CDC guidelines, (2) Inventory of possible forecasting scenarios (e.g., indicated, not indicated), and (3) Translation of immunization schedules into production rules. This process allows rule authors to apply a consistent model for a large set of rules that are both highly complex and require frequent maintenance.

References:

[1] Zhu V, Grannis S, Rosenman M, Downs S, Evaluation of clinical decision support algorithm for patient-specific childhood immunization *Artif Intell Med* 2012. 56(1):51-7

[2] Immunization Schedules. Centers for Disease Control and Prevention: *http://www.cdc.gov/vaccines/schedules/index.html*

Figure 1 - Sequence in which each rule scenario is evaluated for the CDC immunization guidelines

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┌──────────────────┐  N  ┌──────────────────┐  Y  ┌──────────────┐     ┌──────────────┐  N  ┌──────────────────┐     ┌──────────────┐  N  ┌──────────────────┐
│ Is patient       │ ──> │ Are previous     │ ──> │ Is patient   │ ──> │ Is patient   │ ──> │ Are there        │ ──> │ Is patient   │ ──> │ Indeterminate    │
│ contraindicated? │     │ administrati     │     │ at high      │     │ not          │     │ precautions?     │     │ indicated?   │     │                  │
│                  │     │ ons valid ?      │     │ risk?        │     │ indicated ?  │     │                  │     │              │     │                  │
└──────────────────┘     └──────────────────┘     └──────────────┘     └──────────────┘     └──────────────────┘     └──────────────┘     └──────────────────┘
         │ Y                      │ N                                          │ Y                                           │ Y                      │ Y
         ▼                        ▼                                            ▼                                             ▼                        ▼
   Vaccine not            Vaccine not                                    Vaccine not                                   Vaccine              Vaccine not
   indicated              indicated, use                                 indicated                                     indicated            indicated, use
                          clinical judgment                                                                                                 clinical judgment
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