Immunization Calculation Engine (ICE): an Open Source Clinical Decision Support System for Integration with Health Information Systems

OSEHRA Architecture Workgroup
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Topics

- The Business Case for CDS for Immunizations
- Origins of ICE Project
- How Does ICE Work?
- Current Users and Future Plans
Business Case for CDS for Immunization
Examples of Immunization Forecasting

Evaluations (of immunization history)

- The Polio shot that was administered to the patient on June 1, 2013 was **INVALID**.
- The Td shot that was administered to the patient on March 15, 2014 was **VALID**.

Recommendations

- The patient’s next Meningococcal vaccine is **DUE ON SEPTEMBER 20, 2015**.
- The patient has **COMPLETED** their MMR immunizations.
Obstacles to Implementing and Maintaining CDS for Immunizations

- Decisions change simply with the passage of time (patient ages)
- 36+ immunizations by age 12
- New vaccines coming to market
- Evolving guidelines from the Advisory Committee on Immunization Practices (ACIP)
- Different protocols followed in different clinical settings
- Often dependence on one or two key staff member to maintain
- Burden of regression testing – test cases age
- Competing priorities, both for EHR/PHRs and public health
- Lack of consistent funding to support ongoing maintenance
Complex! – (one of 4 pages of footnotes)

**Notes**

Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2019

**Pneumococcal vaccination** (minimum age: 6 weeks; PCV13, 2 years; PPV23)

- **Routine vaccination with PCV13**
  - 4-dose series at 2-4-6, 12-15 months
  - 1 dose for healthy children age 24-29 months with any other pneumococcal PCV13 series
  - For other catch-up guidance, see Table 2.

- **Special situations**
  - High-risk conditions: Both high PCV13 and PPV23 are indicated, administer PCV13 first, PCV13 and PPV23 should not be administered during same visit.
  - Chronic heart disease (particularly cyanotic congenital heart disease and cardiac failure), chronic lung disease (including asthma treated with high-dose oral corticosteroids), diabetes mellitus:
    - Age 2-5 years
      - Any pneumococcal series with:
        - PCV13 doses: 1 dose PCV13 at least 8 weeks after any prior PCV13 dose
        - Less than 3 PCV13 doses: 2 doses PCV13 at least 8 weeks after the most recent dose and administered 8 weeks apart
        - History of PPV23: 1 dose PPV23, at least 8 weeks after any prior PCV13 dose
    - Age 6-18 years
      - No history of PPV23: 1 dose PPV23 at least 8 weeks after any prior PCV13 dose

- **Cerebrospinal fluid leak, cochlear implant:**
  - Age 2-5 years
    - Any pneumococcal series with:
      - PCV13 doses: 1 dose PCV13 at least 8 weeks after any prior PCV13 dose
      - Less than 3 PCV13 doses: 2 doses PCV13 at least 8 weeks after the most recent dose and administered 8 weeks apart
      - History of PPV23: 1 dose PPV23, at least 8 weeks after any prior PCV13 dose
  - Age 6-18 years
    - No history of PPV23: 1 dose PPV23 at least 8 weeks after any prior PCV13 dose

- **Rotavirus vaccination** (minimum age: 6 weeks)

  - **Routine vaccination**
    - Rotate: 3-dose series at 2 and 4 months.
    - Rotate: 3-dose series at 2, 4, and 6 months.
    - Any dose in the series is effective. Rotate to 4-dose series.
  - **Catch-up vaccination**
    - Do not start the series once after age 15 weeks.
    - The maximum age for the final dose is 8 months.
    - For other catch-up guidance, see Table 2.

**Tetanus, diphtheria, and pertussis (Tdap) vaccination** (minimum age: 11 years for routine vaccination, 8 years for catch-up vaccination)

- **Routine vaccination**
  - Adolescents age 11-12 years: 1 dose Tdap
  - Pregnancy: 1 dose Tdap during each pregnancy, preferably in early pregnancy, preferably between 20-26 weeks.
  - Tdap may be administered regardless of the interval since the last tetanus- and diphtheria-containing vaccine.

- **Catch-up vaccination**
  - Adolescents age 12-18 years who have not received Tdap: 1 dose Tdap, then Td booster every 10 years.
  - Persons age 7-18 years not fully immunized with DTaP: Tdap as part of the catch-up series (preferably the first dose).
    - Additional doses are needed, use Td.
  - Children age 7-10 years who receive Tdap inadvertently or as part of the catch-up series should receive the routine Tdap dose at 11-12 years.
  - DTaP inadvertently given after the 7th birthday.
    - Child age 7-10 years: DTaP may count as part of catch-up series.
    - Routine Tdap dose at 11-12 should be administered.
  - Adolescent age 11-18 years: Count dose of DTaP as the adolescent Tdap booster.
  - For other catch-up guidance, see Table 2.
  - For information on use of Tdap or Td as tetanus prophylaxis in wound management, see www.cdc.gov/mmwr/ volume47/ rr/ rr4702.htm.

**Varicella vaccination** (minimum age: 12 months)

- **Routine vaccination**
  - 3-dose series: 12-15 months, 4-6 years.
    - Dose 2 may be administered as early as 3 months after dose 1 in a 4-dose schedule within 4 weeks may be counted.

- **Catch-up vaccination**
  - Ensure persons age 7-18 years without evidence of immunity (age 16 years): at www.cdc.gov/travel/vaccine/1616v9.pdf have:
    - 2 doses series:
      - Ages 7-12 years: routine interval 3 months (minimum interval 4 weeks).
      - Ages 13 years and older: routine interval 4-8 weeks (minimum interval 4 weeks).
    - The maximum age for use of MMR is 12 years.

08/2019

Centers for Disease Control and Prevention | Recommended Child and Adolescent Immunization Schedule, United States, 2019 | Page 8
But a good candidate for development!

- Routine, lifelong events
- With all its complexity, knowledge relatively stable with general consensus clinically
- Good results achievable; serves as a good “test case” for CDS overall

*Clinical Decision Support for Immunizations (CDSi): A Comprehensive, Collaborative Strategy, Biomedical Informatics Insights, Suppl. 2, October 2016.*

Clinical Decision Support

- More commonly referred to as vaccine forecasting and evaluation services by the immunization community.
- Performed by many different computer systems:
  - Electronic Health Record Systems (EHRs)
  - Immunization Information Systems (IIS)
  - Stand-alone applications – Web-based schedulers, smart phone apps, etc.
Origins of ICE Project
## Goal of the ICE Project

Create an immunization decision support system that:

<table>
<thead>
<tr>
<th>Objective</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supports routinely administered vaccine groups</td>
<td>• Supports 16 vaccine groups from birth through adulthood</td>
</tr>
<tr>
<td>Promotes clinical best practices</td>
<td>• Follows ACIP recommendations</td>
</tr>
<tr>
<td>Adapts to changing requirements</td>
<td>• Informed by CDC’s CDSi project</td>
</tr>
<tr>
<td>Easily integrates with IIS and other health systems</td>
<td>• Tools that allow self-administration where practical</td>
</tr>
<tr>
<td>Software and knowledge base freely available</td>
<td>• Automated testing tool w/2,700+ test cases</td>
</tr>
<tr>
<td></td>
<td>• Engineered for high performance and scalability</td>
</tr>
<tr>
<td></td>
<td>• Standards-based architecture and APIs</td>
</tr>
<tr>
<td></td>
<td>• Variety of deployment options</td>
</tr>
<tr>
<td></td>
<td>• Standard, permissive open-source license (LGPL v3)</td>
</tr>
<tr>
<td></td>
<td>• Downloadable from public website</td>
</tr>
</tbody>
</table>
Our Principles

- Changes to the Open Source software should be available to all users.
- A base set of rules developed by consensus should be maintained and be freely available to all users.
- Alternate rule sets may or may not be freely available at the discretion of the organizations that create them or sponsor their creation.
- Resources and activities should be leveraged across participants as much as possible.
- Anyone may create products with “enhanced features” that must comply with the Open Source license but might not be freely available.
The “ICE Vision”

- **ACIP**: Adherence to appropriate clinical guidelines (ACIP)
- **Standards**: Standards-based technical architecture and application programming interface (API)
- **Easy Integration**: Support for a growing range of relevant APIs for invoking and receiving responses from the ICE service, making it easy to integrate ICE with a wide variety of other systems
- **Performance**: High performance and high scalability
The “ICE Vision” (cont.)

- **Knowledge Base**: Published knowledge base, including complete documentation of the ICE immunization schedule, ICE installation process, and ICE API(s)

- **Open Source**: Available under a standard permissive Open Source license.

- **Variety of Sectors**: Use within both public sector and private sector systems

- **Self-Administration**: Tools that allow self-administration where practical
Original ICE Collaborators

- New York City Citywide Immunization Registry
- HLN Consulting, LLC
- Alabama Dept of Public Health
- OpenCDS Team
  - Software platform and toolkit
  - Open source
  - Standards-based
  - Web Service interface
- Collaborative project: Dr. Kensaku Kawamoto at University of Utah
How Does ICE Work?
Inputs to ICE

- Patient parameters
  - Date of birth
  - Gender
  - Immunization history (vaccine and admin date)
  - Disease immunity
    - Proof of immunity
    - History of disease

- Situational parameters
  - Immunization schedule identifier
  - Date of evaluation
Outputs from ICE

- Evaluation - of each Dose
  - Evaluation = \{Valid, Invalid, or Accepted\}
  - Invalid Reason(s), for each Invalid dose

- Recommendation - for each Vaccine Group
  - Recommendation = \{Recommended, Future recommended, Conditional, or Not recommended\}
  - Reason
  - Dates
    - Earliest Date
    - Recommended Date
    - Overdue Date
Sample ICE Deployment

ICE Software System

- CDS Admin Tool (CAT)
  - Code System Editor
  - Vaccine Editor
  - Series Editor
  - Rule Editor
  - Test Editor

ICE Web Service

- OpenCDS

Immunization Registry

Provider

Subject Matter Experts

HL7/OMG CDSS Web Service Interface

SOAP

vMR

DOB

Gender

IZ History (CVX, Administration Date)

Disease Indicators (ICD10 and LOINC)

Evaluation of IZ History + Reason

Recommendation for each Vaccine Group + Reason

ICE Web Service

OpenCDS
Pre-Configured Support for Vaccines in these Vaccine Groups

1. DTP  
2. H1N1  
3. Hep A  
4. Hep B  
5. HPV  
6. Influenza  
7. Meningococcal ACWY  
10. Meningococcal B  
11. MMR  
12. Pneumococcal  
13. Polio  
14. Rotavirus  
15. Varicella  
16. Zoster
Easy to Adopt and Integration

- Open source (GNU LGPL v3)
- Java-based system runs on a wide variety of server platforms
- Can be deployed in a variety of ways
- Standards-based Web Service interface

Comprehensive Documentation

- Public Wiki – www.cdsframework.org
- Implementation Guide for Integrating with ICE
- ICE Default Immunization Schedule
- Binary Releases
- Source Code
Software Architecture

- ICE/OpenCDS
  - Servlet Container (Java EE 6 or 7 compliant)
  - JBoss Drools (rule engine/database)
  - HL7 Decision Support Service "DSS" (web service interface)
  - HL7 Virtual Medical Record "vMR" (data model)
- CAT (CDS Administration Tool)
  - Application Server (Java EE 6 compliant)
  - JavaServer Faces (GUI)
  - Enterprise JavaBeans (business logic)
  - JDBC compliant database
“ICE Client” - Free Tool to Try ICE

- Enables anyone to easily try ICE
- Simple GUI for creating/submitting sample patient data and seeing ICE response/results
- Uses instance of ICE Service hosted by HLN
- Shows vMR-formatted version of sample patient data from user, formatted by client app
- Shows raw vMR-formatted output, returned by ICE instance hosted on HLN server
### Patient Info

**Name:** Jane Smith  
**DOB:** 2018-02-25  
**Gender:** F  
**Evaluation Date:** 2018-04-25  
**Age @Evaluation:** 0y 2m 0d

### Patient Output Grid

**Note:** ICE is returning the Earliest Date and Overdue Date for selected vaccine groups. See the [ICE News page](https://example.com) for more details.

<table>
<thead>
<tr>
<th>Vaccine Group</th>
<th>Recommendations</th>
<th>Evaluations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HepB</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Recommendation Date: 2018-06-25  
Earliest Date: N/A  
Status: FUTURE_RECOMMENDED  
Message: DUE_IN_FUTURE  
Vaccine Group: HepB | | |
| **DTP**       |                 |             |
| Recommendation Date: 2018-04-25  
Overdue Date: N/A  
Earliest Date: N/A  
Status: RECOMMENDED  
Message: DUE_NOW  
Vaccine: DTP (105) | | |
| **Hib**       |                 |             |
| Recommendation Date: 2018-04-25  
Overdue Date: N/A  
Earliest Date: N/A  
Status: RECOMMENDED  
Message: DUE_NOW  
Vaccine Group: Hib | | |
| **Polio**     |                 |             |
| Recommendation Date: 2018-04-25  
Overdue Date: 2018-06-21  
Earliest Date: 2018-04-09  
Status: RECOMMENDED  
Message: DUE_NOW  
Vaccine Group: Polio | | |
Current Users and Future Plans
Deployments of ICE

- eClinicalWorks, National EHR (December 2013)
- CareDox, National PHR (November 2014)
- Denver Public Health (July 2016)
- Selected and Tested by Veteran’s Administration
- NY Presbyterian/Columbia U. Medical Center (June 2017)
- New Jersey IIS (January 2018)
- GE Centricity / Health 1 Technologies
- Michigan IIS (December 2018)
Transitioning to ICE

- Rhode Island IIS
  - Deployed in a Test environment
  - Includes “look-back” feature to view prior forecasts for invalid doses
  - Going live in Spring/Summer 2019

- New York City IIS
  - Doing integration work now
  - Going live in 2nd half of 2019

- Indian Health Services
  - Transitioning to ICE in mid-2020
  - Have begun integration work
  - Comparing current forecaster with ICE
  - May need additional features in ICE to meet IHS’s needs

- Other organizations evaluating ICE…
## ICE Future Plans

<table>
<thead>
<tr>
<th>ICE Feature</th>
<th>Category</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule updates</td>
<td>ACIP Update</td>
<td>March 2019: Release v1.16.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Changes with 2019 Immunization Schedule</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Updates from February 2019 ACIP Meeting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Updates to align with CDSi</td>
</tr>
<tr>
<td>HALO Rules</td>
<td>Product</td>
<td>Health, Age, Lifestyle, Occupation input values</td>
</tr>
<tr>
<td>CAT Authoring Tool</td>
<td>Product</td>
<td>Allows users to author School Rules (and other rules) on top of ICE forecasting</td>
</tr>
<tr>
<td>‘Assumed Complete’ Feature</td>
<td>ICE</td>
<td>Option for a provider to indicate that a patient has had all of their doses to complete a vaccine group series</td>
</tr>
<tr>
<td>Forecast Expiration Date</td>
<td>Produce</td>
<td>Date at which (but not before which) the patient’s record should be re-evaluated</td>
</tr>
<tr>
<td>FHIR Compatibility for ICE Service</td>
<td>Product</td>
<td>Tied to ballot for FHIR HL7 IG for Immunization</td>
</tr>
</tbody>
</table>
ICE Resources

- Basic information: https://www.hln.com/ice/
- Main public wiki page:
  https://cdsframework.atlassian.net/wiki/display/ICE/Home
- Wiki page with documentation of the rules/philosophy:
  https://cdsframework.atlassian.net/wiki/display/ICE/Default+Immuni
  zation+Schedule
- Software download/documentation page:
  https://cdsframework.atlassian.net/wiki/display/ICE/Downloads
- Feature Article:
  http://www.openhealthnews.com/articles/2019/anatomy-public-
  health-open-source-project-hlns-immunization-calculation-engine-ice
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