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

OSEHRA Architecture Workgroup

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Noam H. Arzt, PhD, FHIMSS, FAMIA

President, HLN Consulting, LLC

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 Meningococal vaccine is **DUE ON SEPTEMBER 20, 2015**.
- The patient has **COMPLETED** their MMR immunizations.

Obstacles to Implementing and Maintaining CDS for Immunizations

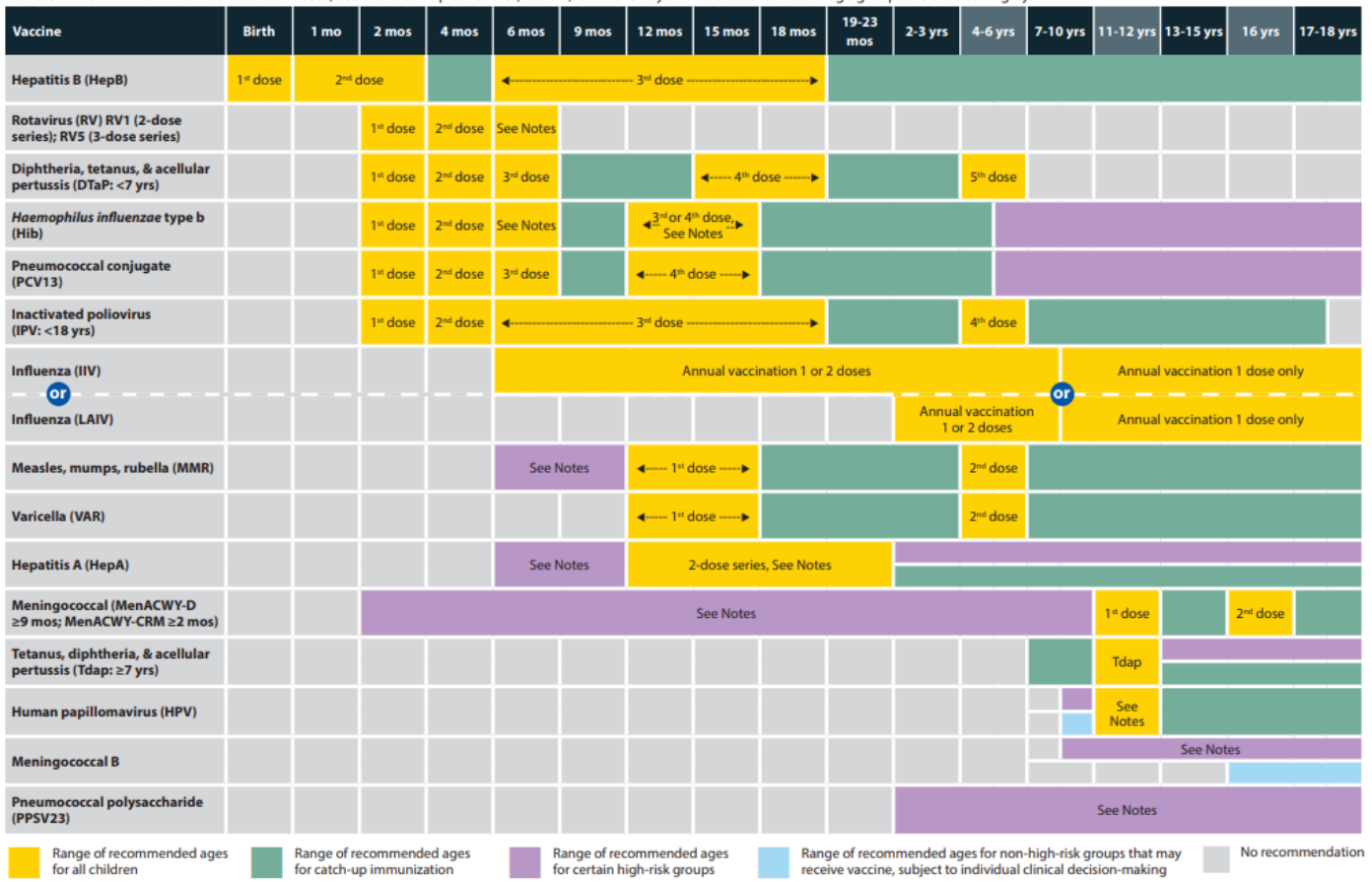
- Decisions change simply with the passage of time (patient ages)
- 36+ immunizations by age 12
- New vaccines coming to market
- Evolving guidelines from the Advisory Committee on Immunization Practices (ACIP)
- Different protocols followed in different clinical settings
- Often dependence on one or 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

Recommended Immunization Schedule Birth - 18 Years

(http://www.cdc.gov/vaccines/schedules/downloads/child/0-18yrs-child-combined-schedule.pdf)

Table 1 Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger
United States, 2019

These recommendations must be read with the Notes that follow. For those who fall behind or start late, provide catch-up vaccination at the earliest opportunity as indicated by the green bars in Table 1.
To determine minimum intervals between doses, see the catch-up schedule (Table 2). School entry and adolescent vaccine age groups are shaded in gray.



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 [PPSV23])

Routine vaccination with PCV13
- 4-dose series at 2, 4, 6, 12–15 months

Catch-up vaccination with PCV13
- 1 dose for healthy children age 24–59 months with any incomplete* PCV13 series
- For other catch-up guidance, see Table 2.

Special situations
High-risk conditions below: When both PCV13 and PPSV23 are indicated, administer PCV13 first. PCV13 and PPSV23 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 incomplete* series with:
  - 3 PCV13 doses: 1 dose PCV13 (at least 8 weeks after any prior PCV13 dose)
  - Less than 3 PCV13 doses: 2 doses PCV13 (8 weeks after the most recent dose and administered 8 weeks apart)
- No history of PPSV23: 1 dose PPSV23 (at least 8 weeks after any prior PCV13 dose)

Age 6–18 years
- No history of PPSV23: 1 dose PPSV23 (at least 8 weeks after any prior PCV13 dose)

Cerebrospinal fluid leak, cochlear implant:

Age 2–5 years
- Any incomplete* series with:
  - 3 PCV13 doses: 1 dose PCV13 (at least 8 weeks after any prior PCV13 dose)
  - Less than 3 PCV13 doses: 2 doses PCV13, 8 weeks after the most recent dose and administered 8 weeks apart
- No history of PPSV23: 1 dose PPSV23 (at least 8 weeks after any prior PCV13 dose)

Age 6–18 years
- No history of either PCV13 or PPSV23: 1 dose PCV13, 1 dose PPSV23 at least 8 weeks later
- Any PCV13 but no PPSV23: 1 dose PPSV23 at least 8 weeks after the most recent dose of PCV13
- PPSV23 but no PCV13: 1 dose PCV13 at least 8 weeks after the most recent dose of PPSV23

Sickle cell disease and other hemoglobinopathies; anatomic or functional asplenia; congenital or acquired immunodeficiency; HIV infection; chronic renal failure; nephrotic syndrome; malignant neoplasms, leukemias, lymphomas, Hodgkin disease, and other diseases associated with treatment with immunosuppressive drugs or radiation therapy; solid organ transplantation; multiple myeloma:

Age 2–5 years
- Any incomplete* series with:
  - 3 PCV13 doses: 1 dose PCV13 (at least 8 weeks after any prior PCV13 dose)
  - Less than 3 PCV13 doses: 2 doses PCV13 (8 weeks after the most recent dose and administered 8 weeks apart)
- No history of PPSV23: 1 dose PPSV23 (at least 8 weeks after any prior PCV13 dose) and a 2nd dose of PPSV23 5 years later

Age 6–18 years
- No history of either PCV13 or PPSV23: 1 dose PCV13, 2 doses PPSV23 (dose 1 of PPSV23 administered 8 weeks after PCV13 and dose 2 of PPSV23 administered at least 5 years after dose 1 of PPSV23)
- Any PCV13 but no PPSV23: 2 doses PPSV23 (dose 1 of PPSV23 administered 8 weeks after the most recent dose of PCV13 and dose 2 of PPSV23 administered at least 5 years after dose 1 of PPSV23)
- PPSV23 but no PCV13: 1 dose PCV13 at least 8 weeks after the most recent PPSV23 dose and a 2nd dose of PPSV23 administered 5 years after dose 1 of PPSV23 and at least 8 weeks after a dose of PCV13

Chronic liver disease, alcoholism:

Age 6–18 years
- No history of PPSV23: 1 dose PPSV23 (at least 8 weeks after any prior PCV13 dose)

*An incomplete series is defined as not having received all doses in either the recommended series or an age-appropriate catch-up series. See Tables 8, 9, and 11 in the ACIP pneumococcal vaccine recommendations (www.cdc.gov/mmwr/pdf/rr/rr5911.pdf) for complete schedule details.

Rotavirus vaccination (minimum age: 6 weeks)

Routine vaccination
- **Rotarix:** 2-dose series at 2 and 4 months.
- **RotaTeq:** 3-dose series at 2, 4, and 6 months.

If any dose in the series is either **RotaTeq** or unknown, default to 3-dose series.

Catch-up vaccination
- Do not start the series on or after age 15 weeks, 0 days.
- The maximum age for the final dose is 8 months, 0 days.
- For other catch-up guidance, see Figure 2.

Tetanus, diphtheria, and pertussis (Tdap) vaccination (minimum age: 11 years for routine vaccination, 7 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 part of gestational weeks 27–36
- Tdap may be administered regardless of the interval since the last tetanus- and diphtheria-toxoid-containing vaccine.

Catch-up vaccination
- **Adolescents age 13–18 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:** 1 dose Tdap as part of the catch-up series (preferably the first dose); if 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/volumes/67/rr/rr6702a1.htm.

Varicella vaccination (minimum age: 12 months)

Routine vaccination
- 2-dose series: 12–15 months, 4–6 years
- Dose 2 may be administered as early as 3 months after dose 1 (a dose administered after a 4-week interval may be counted).

Catch-up vaccination
- Ensure persons age 7–18 years without evidence of immunity (see *MMWR* at www.cdc.gov/mmwr/pdf/rr/rr5604.pdf) have 2-dose 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 *MMRV* is 12 years.

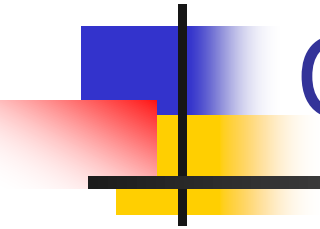
But a good candidate for development!

- 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. <http://www.la-press.com/clinical-decision-support-for-immunizations-cdsi-a-comprehensive-colla-article-a5971-abstract?article_id=5971>

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:

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

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?

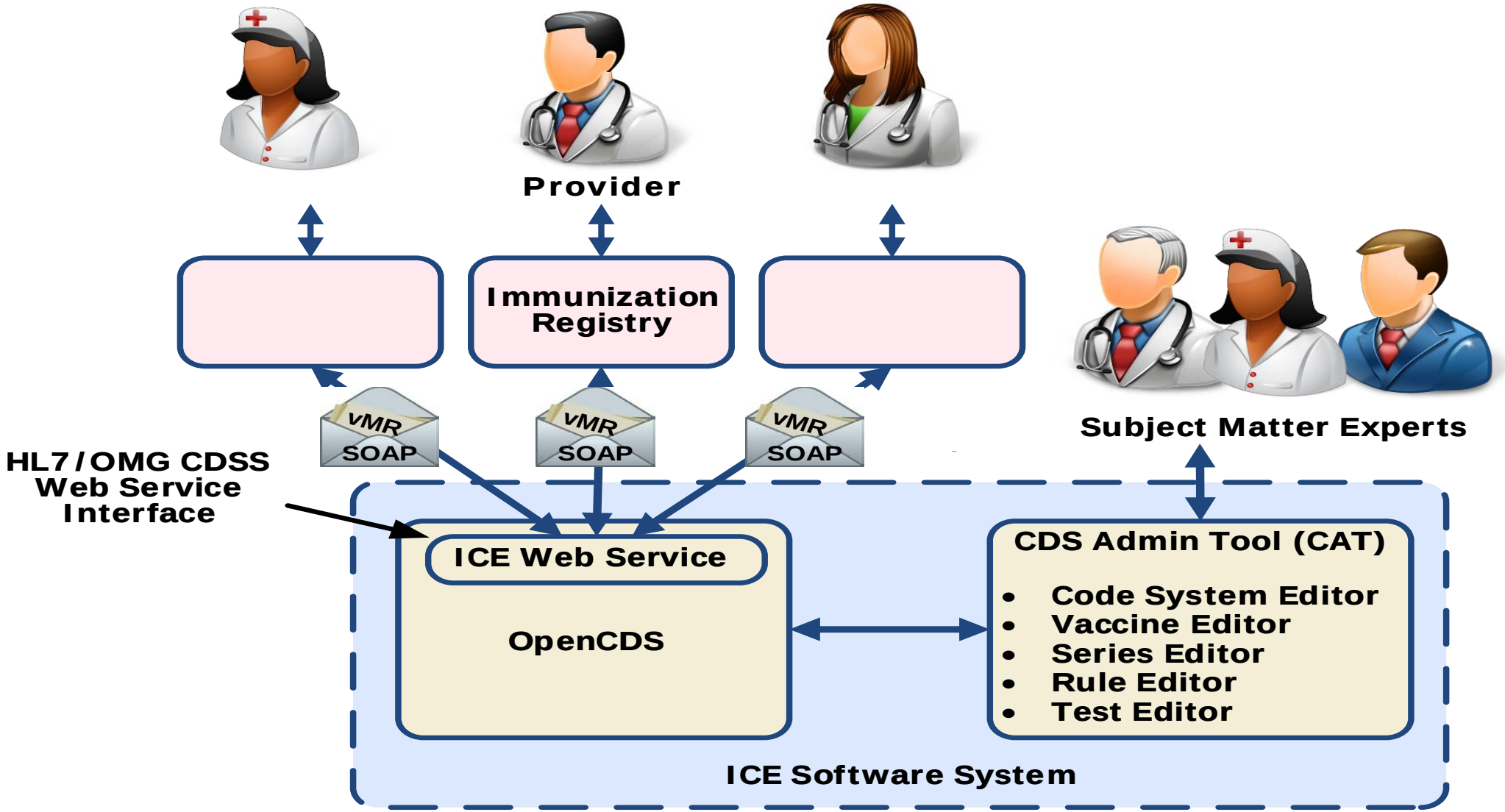
Inputs to ICE

- 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



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 sever 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 Containe
  - JBoss Drools (ru
  - HL7 Decision Su
  - HL7 Virtual Med
- CAT (CDS Admir
  - Application Serv
  - JavaServer Face
  - Enterprise JavaE
  - JDBC compliant

"ICE Client" - Free Tool to Try ICE

- Browser-based app: http://cds.hln.com/iceweb/
- 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

ICE Client Application Sample Screenshot

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 for more details.

Vaccine Group	Recommendations	Evaluations
HepB	Recommendation Date: 2018-06-25 Overdue Date: N/A Earliest Date: N/A Status: FUTURE_RECOMMENDED Message: DUE_IN_FUTURE Vaccine Group: HepB	Date: 2018-04-25 Age: 0y 2m 0d Valid: true Vaccine: Hep B, adolescent or pediatric (08)
DTP	Recommendation Date: 2018-04-25 Overdue Date: N/A Earliest Date: N/A Status: RECOMMENDED Message: DUE_NOW Vaccine: DTaP NOS (107)	
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: 2018-04-08 Status: RECOMMENDED Message: DUE_NOW Vaccine Group: Polio	

Current Users and Future Plans

Deployments of ICE

- eClinicalWorks, National EHR (Dec
- CareDox, National PHR (Novembe
- Denver Public Health (July 2016)
- Selected and Tested by Veteran's
- NY Presbyterian/Columbia U. Medi
- New Jersey IIS (January 2018)
- GE Centricity / Health 1 Technolog
- 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

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

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+Immunization+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

Contact Information

Noam H. Arzt

President, HLN Consulting, LLC

858-538-2220 (Voice)

arzt@hln.com

@NoamArzt

http://www.hln.com/noam/