



Cerner  
**code Learning  
Lab** 2019

Remote Decision Support with CDS Hooks

Dennis Patterson  
*Lead Software Engineer*



# The challenge with SMART apps



## Bilirubin Chart

Newborns < 120 hours old

Bilirubin results that are either:

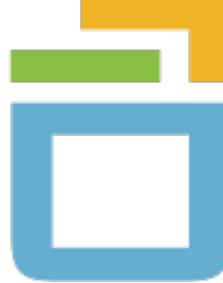
- Not documented

- Outside of the accepted range

The user needs to know the app is [available](#)

The user needs to know the app is [relevant](#)

The user has to [find](#) the app and launch it

C D S H  O K S

# CDS Hooks

*A vendor agnostic remote decision support specification*



Originated from the team behind SMART



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An HL7 standard

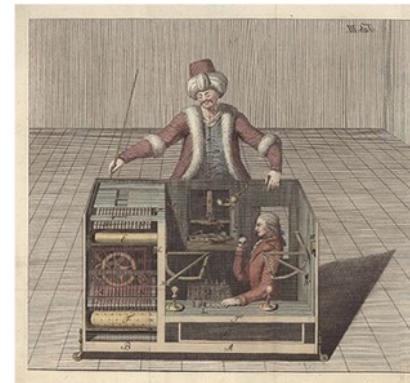
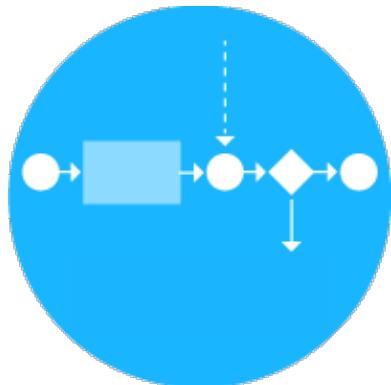
# CDS Service

A service that is:

invoked by the CDS Client via a [hook](#),

evaluates [its own logic](#) using FHIR data,

returns decision support via [cards](#)



# Example Hooks

## patient-view

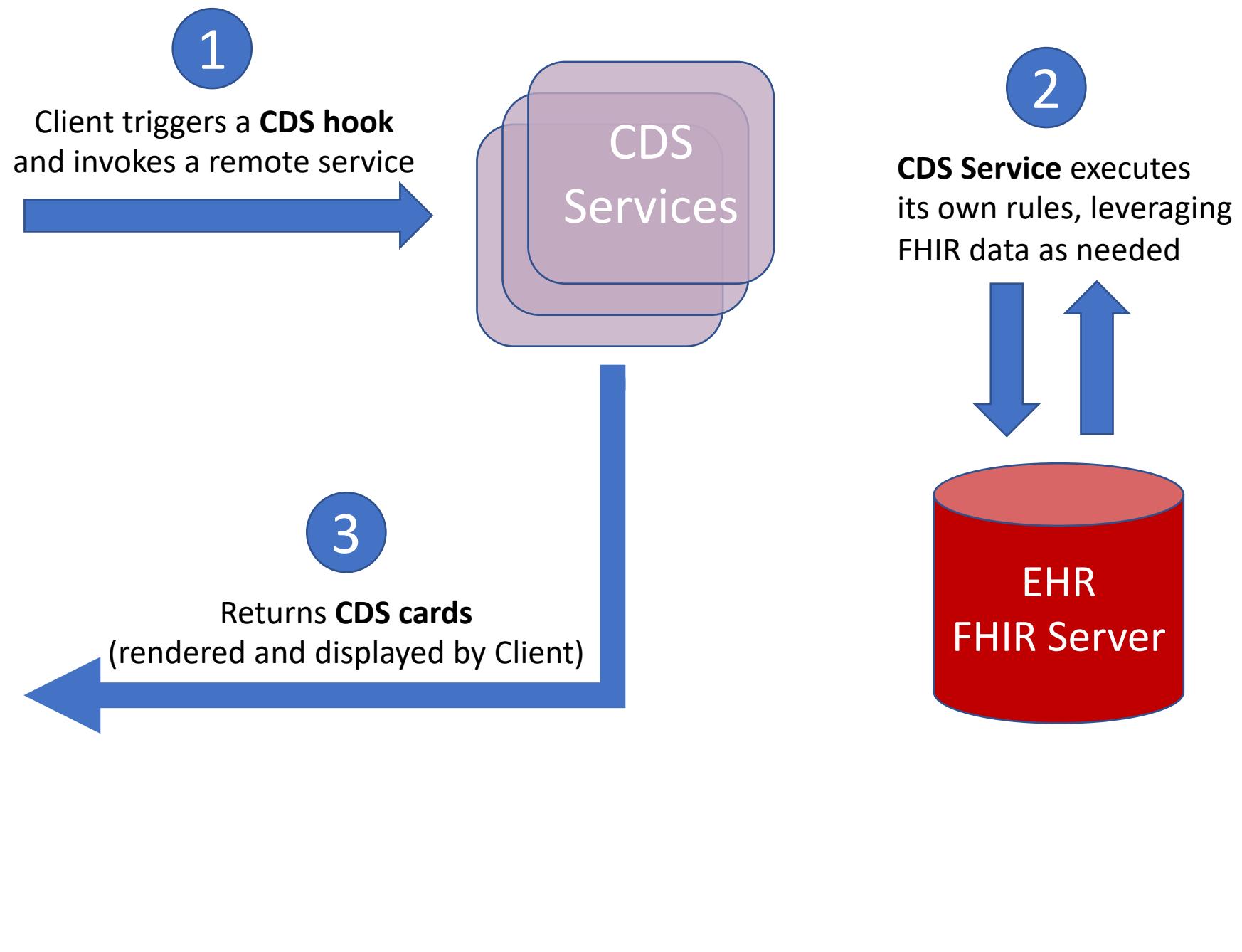
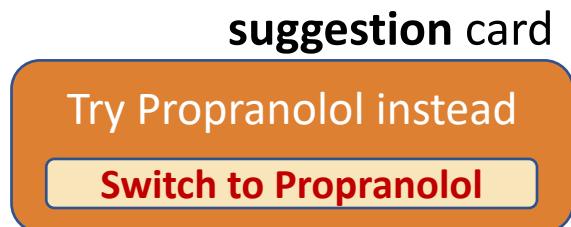
When a patient's chart is opened

## order-select

When a clinician selects one or more orders to place for a patient

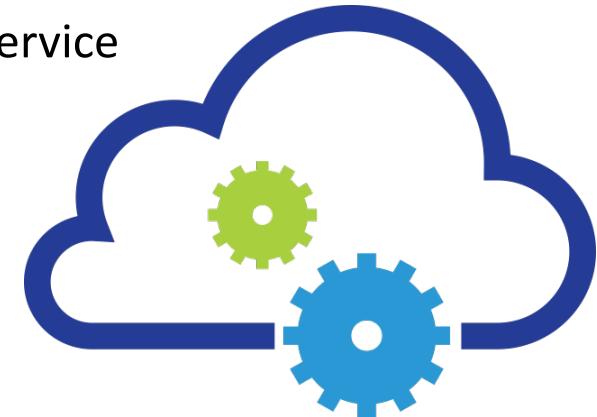
## order-sign

When a clinician is ready to sign one or more orders for a patient





CDS Client



CDS Service

POST https://example.com/cds-services/example-service

```
{  
  "hook": "patient-view",  
  "hookInstance": "b708b3036ac9-a3c4-46d5-819c",  
  "fhirServer": "https://fhir.example.com",  
  "context": {  
    "userId": "Practitioner/789"  
    "patientId": "123",  
  },  
  ...  
}
```



CDS Client



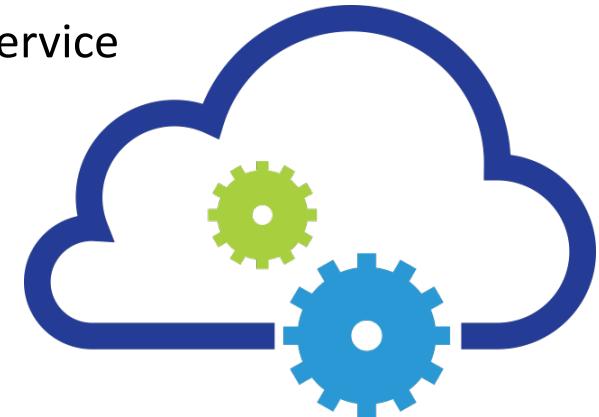
CDS Service

POST <https://example.com/cds-services/example-service>





CDS Client



CDS Service

POST https://example.com/cds-services/example-service

HTTP 1.1/ 200 OK



```
{  
  "cards": [  
    {  
      "summary": "Example card",  
      "indicator": "info",  
      "source": {  
        "label": "Demo CDS Service"  
      } } ] }
```

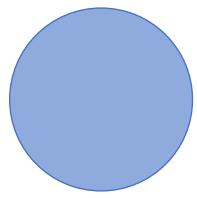
# Cards

- A CDS Service can return any number of cards
- The CDS Client renders each card as it sees fit
- Each card must have:
  - A concise summary (140 characters)
  - An indicator noting the importance of the card
  - Information on the organization or data set that is the source of the card's data

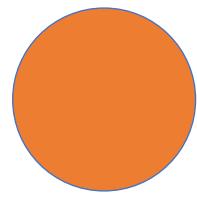
# CDS Service Response JSON

```
{  
  "cards": [  
    {  
      "summary": "Example card",  
      "indicator": "info",  
      "source": {  
        "label": "Demo CDS Service"  
      }  
    }  
  ] }
```

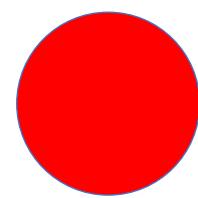
# Card Indicator



Informational

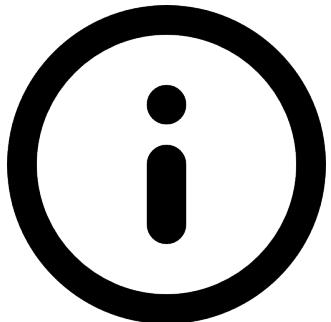


Warning



Critical

# Common Card Examples



## Information Only

Textual information for the provider



## Suggestions

Proposed actions encoded as FHIR resources



## App Links

Proposed SMART app that should be used

### Medication Information

ADRA2A (C/C): The genotype of this patient suggests a reduced response to certain ADHD medications.

Source: [RxCheck](#)

### Medication Alert for lisinopril 5 mg tablet

This medication is not recommended for Black or African American patients.

*82% of providers selected this recommendation.*

 Switch to amiloride 5 mg-hydrochlorothiazide 50 mg tablet

Source: [RxCheck](#)

### ASCVD Risk Alert

12% 10-year risk

69% lifetime risk

Source: [Demo CDS Service](#)

 ASCVD Risk Calculator

Cards can contain any combination of information, suggestions, and links

## Medication Alert

Source: RxCheck



### lisinopril 5 mg tablet

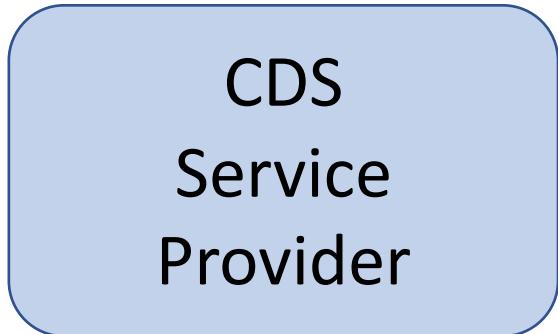
- This medication is not recommended for Black or African American patients.

*82% of providers selected this recommendation.*

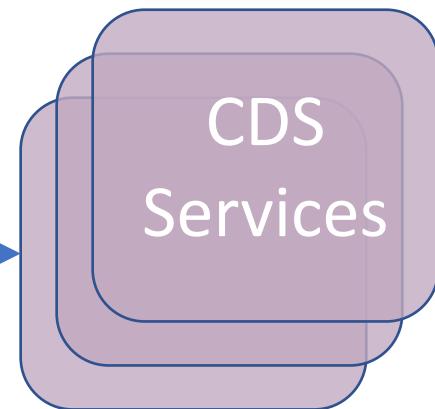
 Switch to amiloride 5 mg-hydrochlorothiazide 50 mg tablet

 Medication Review

**Base** `https://example.com`



**Discovery** `/cds-services`



**Service** `/cds-services/{id}`

# Discovery

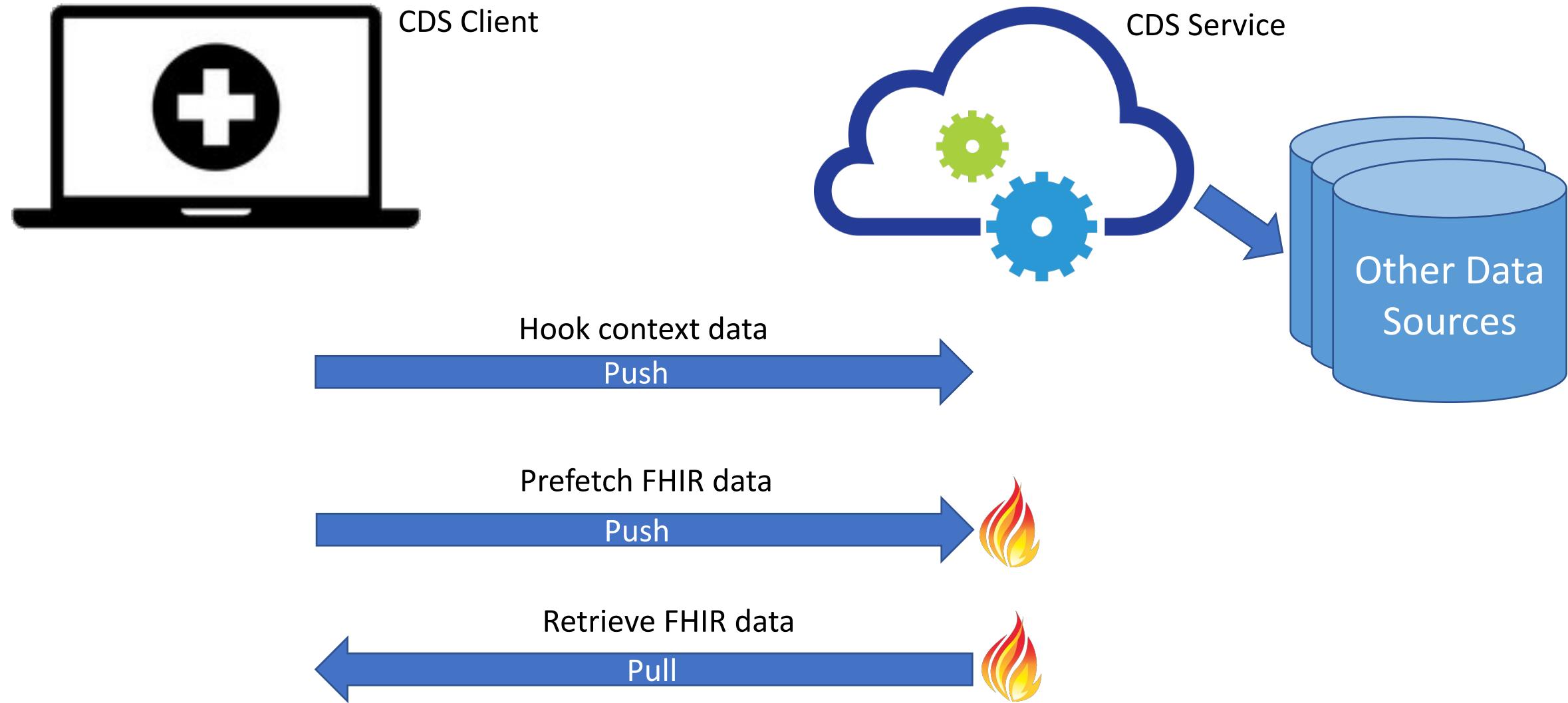
```
GET https://example.com/cds-services
{
  "services": [
    {
      "hook": "patient-view",
      "title": "CDS Service Example",
      "description": "An example CDS service",
      "id": "example-service",
      "prefetch": {
        "patientToGreet": "Patient/{{context.patientId}}"
      }
    },
    { ... }
  }
}
```

# CDS Service Invocation

```
{  
  "services": [  
    {  
      "hook": "patient-view",  
      "title": "CDS Service Example",  
      "description": "An example CDS service",  
      "id": "example-service",  
      "prefetch": true  
    }  
  ]  
}
```

POST <https://example.com/cds-services/example-service>

# Data Access available to a CDS Service



# Hook Context Data

- Data specific to a hook
- Data that all CDS Services using that hook would use
- Can be FHIR data (or references to FHIR data) but not always
- Every hook defines its own context

## Example: patient-view hook

Field	Optionality	Prefetch Token?	Type	Description
userId	REQUIRED	Yes	string	The FHIR resource type + id of the current user eg: Practitioner/1 or Patient/2
patientId	REQUIRED	Yes	string	The FHIR Patient.id of the current patient in context
encounterId	OPTIONAL	Yes	string	The FHIR Encounter.id of the current encounter in context

# Prefetch Data



- Always FHIR data
- Data specific to a given CDS Service
- CDS Clients are not required to honor prefetch requests from CDS Services
- Expressed as FHIR read/search queries

## Example prefetch templates

Prefetch Template	Description
Patient/ { {context.patientId} }	The current FHIR Patient
metadata	The FHIR server's CapabilityStatement

# Why Prefetch?



**Required** Your CDS Service always needs a set of data



**Efficiency** CDS Clients may be able to consolidate duplicate prefetch requests into fewer/optimal requests

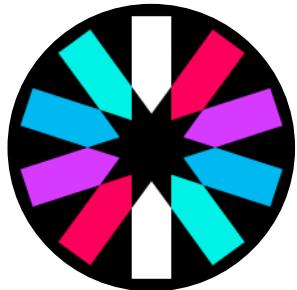


**Performance** CDS Clients may be able to retrieve the data in a more performant manner (in-memory, cached, less latency)

# Security



CDS Client trusts the CDS Service via its TLS endpoint

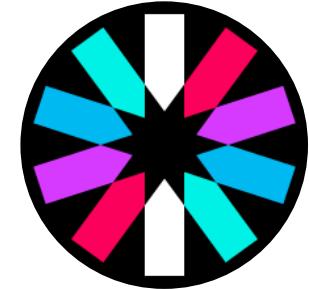


CDS Service trusts the CDS Client via signed JWT



CDS Client provides FHIR access token to CDS Service

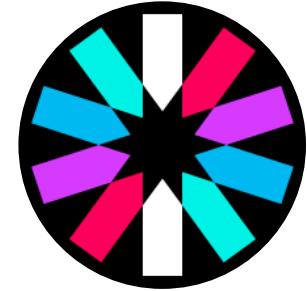
# Security > JWT



```
eyJhbGciOiJIUzI4NCI&lt;lnR5cCI6IkpXVCJ9.eyJpc3MiOiJodHRwczovL2ZoaXIzWhYlMv4YW1wbGUuY29tLyI&lt;br/&gt;ImF1ZCI6Imh0dHBzOi8vY2RzLmV4YW1wbGUub3JnL2Nkcy1zZXJ2aWNlcyc9zb21ILXNlcnpY2UiLCJ0ZW5hb&lt;br/&gt;nQiOiI3MzMwNDQ4MC1kYzI2LTQwMjAtOWU5My1INzUzNjBjMDJjMGIiLCJleHAIojeOMjl1Njg4NjAsImlhdC&lt;br/&gt;I6MTMxMTI4MDk3MCwianRpIjoiZWUyMmlwMjEtZTFiNy00NjExLWJhNWItOGVIYzZhMzNhYzFIIn0.yG3pM&lt;br/&gt;hHF3Bvo1cHLRfv7Rn-BNKJaD4R-0_pITrR0mPwytVLAO9omA9eZ-NfncBa&lt;br/&gt;{
```

```
"iss": "https://ehr.example.com/",&lt;br/&gt;"aud": "https://example.org/cds-services/my-service",&lt;br/&gt;"tenant": "73304480-dc26-4020-9e93-e75360c02c0b",&lt;br/&gt;"exp": 1422568860,&lt;br/&gt;"iat": 1311280970,&lt;br/&gt;"jti": "ee22b021-e1b7-4611-ba5b-8eec6a33ac1e"&lt;br/&gt;}
```

# Security > JWT



Field	Value	Example
iss	The URL of the issuer of the JWT	<a href="https://ehr.example.com">https://ehr.example.com</a>
aud	The CDS Service endpoint being called	<a href="https://example.org/cds-services/my-service">https://example.org/cds-services/my-service</a>
tenant	An opaque string identifying the healthcare organization that is invoking the CDS Hooks request	73304480-dc26-4020-9e93-e75360c02c0b
exp	Time this JWT expires	1422568860
iat	Time at which this JWT was issued	1311280970
jti	Nonce to protect against replay attacks	ee22b021-e1b7-4611-ba5b-8eec6a33ac1e

## Patient View

### Daniel X. Adams

ID: SMART-1288992 Birthdate: 1925-12-23

#### Bilirubin Levels Exceed Threshold

Source: [Intermountain Healthcare](#)



Bilirubin levels are exceeding risk levels. Intervention is necessary.

[HSPC Bilirubin Risk Chart](#)

#### Now seeing: Daniel Adams

Source: [CDS Service Tutorial](#)

[Learn more about CDS Hooks](#)

#### Now seeing: Daniel

Source: [Patient greeting service](#)

CDS Developer Panel

## CDS Developer Panel

### Select a Service

demo-app-link-card - <https://bilirubin-cdshooks.hspconsortium.org/cds-services/demo-app-link-card>

### > Request

### ▽ Response

```
{  
  "cards": [  
    {  
      "summary": "Bilirubin Levels Exceed Threshold",  
      "detail": "<img src='https://content.hspconsortium.org/images/intermountai  
      "indicator": "warning",  
      "source": {  
        "label": "Intermountain Healthcare",  
        "url": "https://intermountainhealthcare.org"  
      },  
      "links": [  
        {  
          "label": "HSPC Bilirubin Risk Chart",  
          "url": "https://bilirubin-risk-chart.hspconsortium.org/launch.html",  
          "type": "smart"  
        }  
      ]  
    }  
  ]  
}
```

### ▽ Messages

# Separation of Concerns

Concern	Owner
Workflow & hooks (triggers)	CDS Client
CDS logic	CDS Service Provider
Initial context data	CDS Client
Additional data	CDS Service Provider (via FHIR or other sources)
CDS presentation	CDS Client



**Epic**



*eClinicalWorks*

THE SYSTEM



**covermymeds**



**fdb**  
First Databank



**HIN**  
Consulting, LLC



**HSPC**  
the healthcare services platform consortium™

**MAYO  
CLINIC**



**QvΣRA**

**zynxhealth**  
PREMIER



**NORTHROP  
GRUMMAN**

**NANTHEALTH**

**ONN**

**ORION  
HEALTH**

**UTHealth**  
The University of Texas Health Science Center at Houston

**MCKESSON**

**elimu  
informatics**

**HARMONIQ**

**PIONETECHS**

**EBSCO** Health

**Intermountain  
Healthcare**

**Cerner**

**Oridashi**

**Epic**

**healthwise®**  
for every health decision®

**global strategies**

**Allscripts™**

**athenahealth**

**eClinicalWorks**

**THE SYSTEM**

**IMO**  
Intelligent Medical Objects

**Lantana**  
CONSULTING GROUP

**U**  
HEALTH



**mcg**

**firely**

**RxREVU**

**Wolters Kluwer**  
Health

**perspecta**



**ENVISION**  
TECHNOLOGY PARTNERS

**HEALTH  
SAMURAI**

**HEALTH**  
UNIVERSITY OF UTAH

**Lush**  
Group Inc.

**stanson** **health**

**PHILIPS**  
Healthcare

**MedImpact**

**MITRE**

**“polyglot”**  
Health Through Understanding™

**syapse**

**Cigna**

**accenture**  
**mModal**

**Clinical Cloud Solutions**

**TABULARASA**  
HEALTHCARE®

**medical-objects**  
CLINICAL APPLICATIONS, MESSAGING AND INTEGRATION

**MERCK  
MANUALS**

# Argonauts ❤️ CDS Hooks



Focused (2017) on use case of pushing SMART apps via a CDS Service upon opening the patient's chart



Funded (2017) external security assessment and threat model



Focused (2019) on use case of pushing appropriate radiology ordering via a CDS Service

# Published!



Released a 1.0 specification in April  
at <https://cds-hooks.hl7.org>

# What's after 1.0?



Capturing decisions



Specific use cases  
(image ordering guidelines, CDC opioid guidelines, etc.)



System-only actions

# Wait, doesn't FHIR already define an approach for CDS?

**Level 5** Providing the ability to reason about the healthcare process



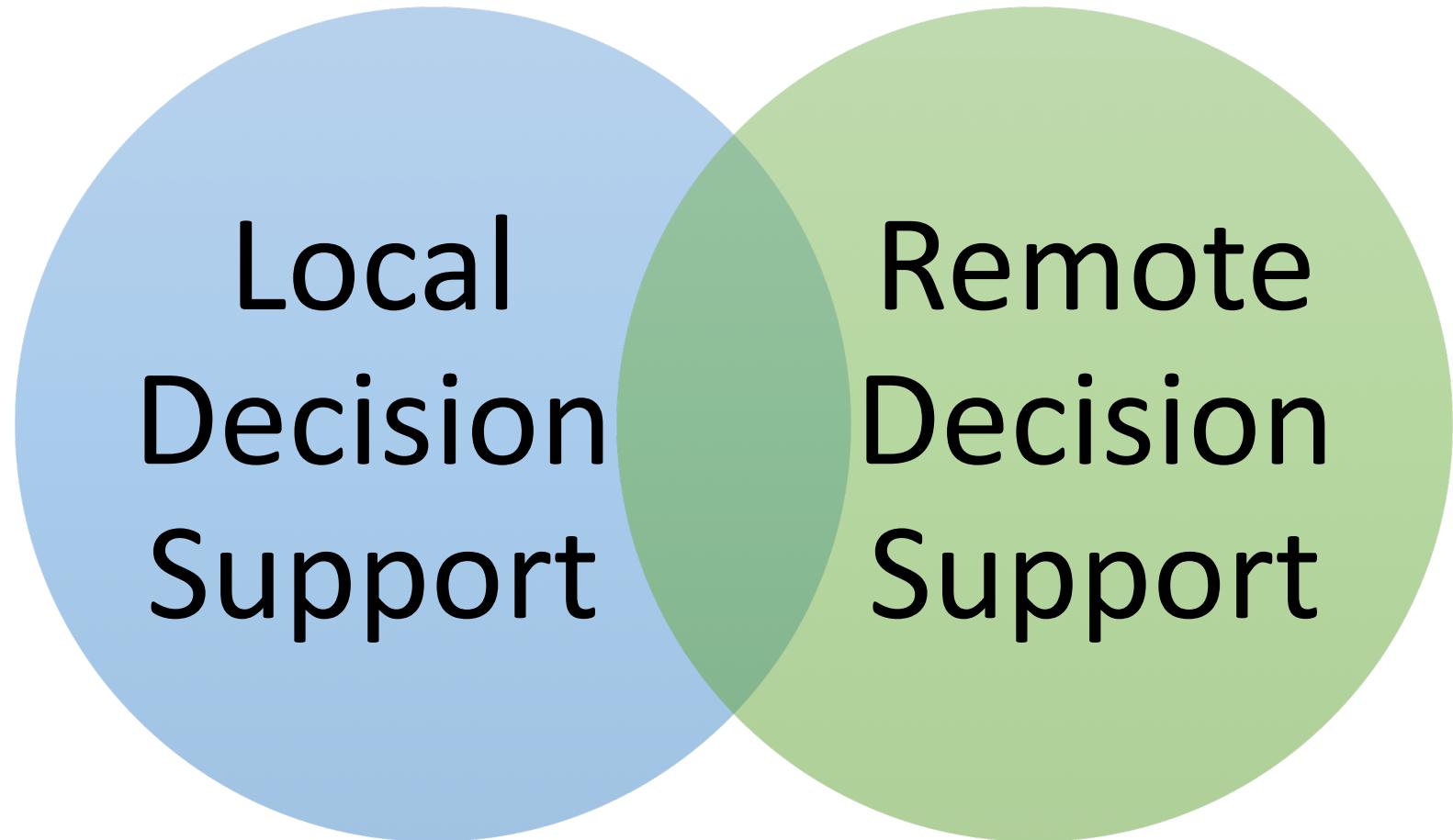
**Clinical Reasoning**

[Library](#), [ServiceDefinition](#) & [GuidanceResponse](#), [Measure](#)/[MeasureReport](#), etc



# Clinical Reasoning

CDS HOOKS



# References



Specification & documentation  
<http://cds-hooks.org>



Sandbox  
<http://sandbox.cds-hooks.org>



Source code  
<https://github.com/cds-hooks>

# Let's code!

Complete the tutorial and  
write your own CDS Service!

[github.com/cerner/cds-services-tutorial](https://github.com/cerner/cds-services-tutorial)

Thanks!

# Addendum

Sample content from CDS vendors  
developing on CDS Hooks



# Healthwise helps people make better health decisions with CDS Hooks

## Review patient education at the moment in care

### Patient Education

*Source: Healthwise*

The following patient education resources were found.

### Conditions

Dementia associated with another disease(2008-08-08)

Essential hypertension(2008-04-20)

Other persistent mental disorders due to conditions classified elsewhere(2007-09-15)

- Medical History and Physical Exam for Dementia or Alzheimer's Disease,
- Memory Problems: Wandering,
- Memory Problems: Tips for Helping the Person With Daily Tasks

## Prevent medication interactions at the time of prescription

### Drug Interactions

*Source: Healthwise*

The following drug interactions were found.

### Interactions

**ACE INHIBITORS; ARBS; ALISKIREN/POTASSIUM PREPARATIONS (moderate)**

lisinopril (bulk) and potassium acetate may interact based on the potential interaction between ACE INHIBITORS; ARBS; ALISKIREN and POTASSIUM PREPARATIONS.

**KEEP VITAMIN K CONTENT OF DIET CONSISTENT. (serious)**

The use of warfarin (bulk) may interact with food in that FOOD HIGH IN VITAMIN K MAY DECREASE EFFECT.

# PerfectChoice™

Helping physicians make the perfect antibiotic choices.

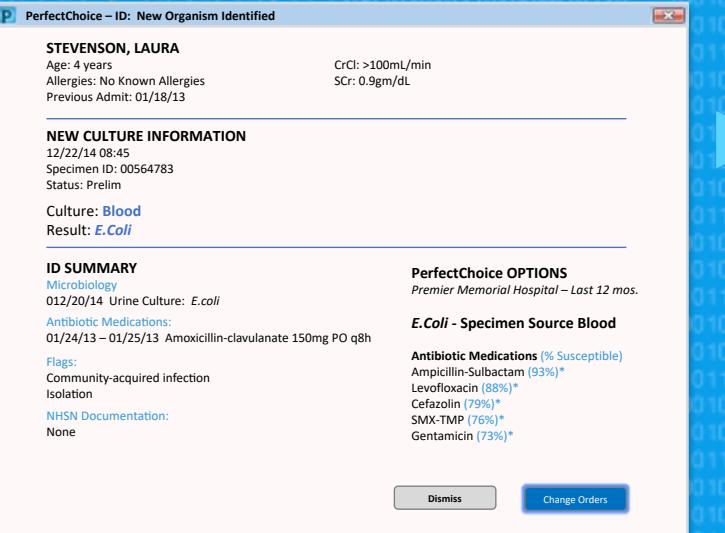
## IDENTIFY.

PerfectChoice Notification: Based on new culture information and facility antibiogram, the following antinefectives have the highest likelihood (% susceptible) of effectively treating the infection.

Source:  
 Launch Premier TheraDoc for more details.

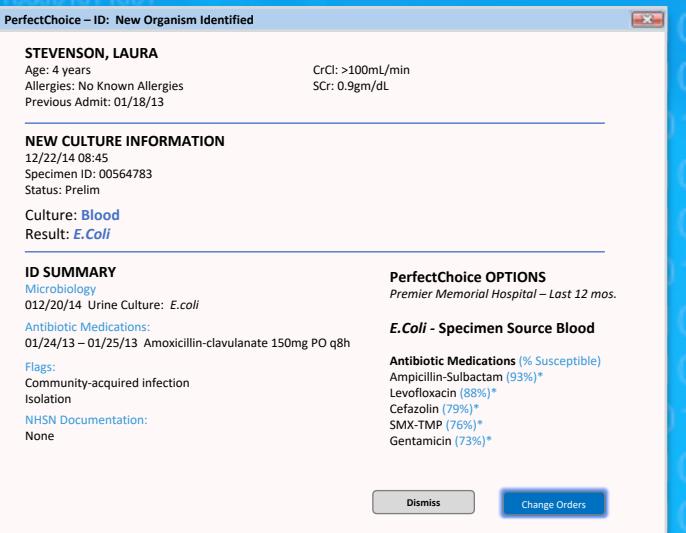
Know the priority patients with new microbiology results with automated surveillance that notifies clinicians in their workflow.

## DECIDE.



View the best antibiotic options based on facility antibiogram in context of the patient's relevant clinical data to reach the right decision.

## ACT.



Access the EMR to make the appropriate medication order decisions.



A Premier Solution

# surescripts® Medication Management for Adherence (CDS Hooks)

Real-time medication adherence insights  
delivered directly into workflow during patient visits

Patient View

**Daniel X. Adams**  
Birthdate: 1925-12-23

Hello Daniel!  
Source: Patient greeting service

Medication Management for Adherence  
Source: Powered by Surescripts

The PDC (Proportion of Days Covered) is calculated by the Pharmacy Benefit Management (PBM) or Health Plan based on claims data. The PDC score is used to communicate the patient's overall adherence.

Lowest PDC score 47% Diabetes as of 10/13/2016 12:17:38 AM

Medication Adherence Profile

**▲ 47% Diabetes** 10/25/2016

Medication	Filled	Supply
METFORMIN HCL - 30.0 MG	9/25/2016	30 days
NDC: 68382075810		

**✓ 85% Cholesterol** 10/25/2016

Medication	Filled	Supply
LOVASTATIN - 90.0 MG	9/25/2016	90 days
NDC: 68180046803		

Bi-directional communication  
to enable users to provide real-time feedback

Medication Adherence  
Adams, Daniel - DOB: 12/23/1925  
Received: 10/25/2016

Health plan records show this patient may not be taking their diabetes medication as instructed. Please talk to your patient about adherence.

Please respond:

Is adherence a confirmed issue?

Yes

Why is adherence an issue?

Patient has been educated on importance of adherence and plans to resume therapy

Patient refuses drug due to cost

Patient refuses drug due to side effects

Patient refuses drug due to other reasons

An unlisted reason

# Stanson Health's CDS Hooks service

## Clinical Advisory

A Choosing Wisely® recommendation from the American Geriatrics Society states:  
Don't use benzodiazepines or other sedative-hypnotics in older adults as first choice for insomnia, agitation or delirium. [more...](#)

lorazepam 1 mg tablet [orderId: 117278] [remove order](#)

EDUCATION 1 2 3 4 5 6 [OVERRIDE](#) [DISMISS](#)

A Choosing Wisely® recommendation from the American College of Cardiology states:  
Don't perform annual stress cardiac imaging or advanced non-invasive imaging as part of routine follow-up in asymptomatic patients. [more...](#)

*you are able to narrow this down when accepting* [select order to remove](#)

a. Computed tomography angiography of coronary arteries [orderId: 1234]  
b. Positron emission tomography myocardial stress imaging using rubidium 81 [orderId: 1235]

EDUCATION 1 2 3 4 [OVERRIDE](#) [DISMISS](#)

Real time, workflow integrated, patient specific, evidence based

Reduces low-value and unnecessary care

Build custom differentials from patient information

## Daniel X. Adams

Birthdate: 1925-12-23

### Recently viewed Diagnoses from VisualDx

Add new Conditions to the problem list

Urticaria  Creutzfeldt-Jakob Disease  Lead Poisoning

### DDx of Medication Reactions in VisualDx

Lisinopril  Hydrochlorothiazide

### Build a Custom Differential in VisualDx

Select a finding to be the Chief Complaint

Hypertension

### Diagnosis Summaries and Images in VisualDx

Primary Hypertension  Osteoarthritis  Dementia  Alzheimer Disease

## Find diagnosis summaries and textbook differentials

### Differential Diagnosis & Pitfalls

- Drug toxicity
- Chronic ethanol consumption (ie, [alcohol use disorder](#))
- [Lead poisoning](#)
- Carbon monoxide poisoning
- Multi-infarct dementia
- [Depression](#)
- [Complex partial seizures](#)
- [Autoimmune encephalopathy](#)
- [Creutzfeldt-Jakob disease](#)

## Differential Diagnosis of a 80+ year old Male

with  Lisinopril  Rash  Reaction 0 to 5 Days After Drug  Smooth Plaque  ADD OR REMOVE FINDINGS



### Urticaria

#### VERY COMMON OR IMPORTANT DIAGNOSIS

Raised, erythematous wheals caused by the release of histamine and other vasoactive substances from mast cells. Urticaria can be triggered by a variety of mechanisms, both allergic and nonallergic. Pruritus, prickling and stinging sensations, or pain may occur with urticaria. Usually resolve within 24 hours without skin sequelae.

[View Diagnosis Details](#)

#### Other Resources:

[UpToDate](#)  [PubMed](#)

Matches 4 of 4 findings: [Edit findings](#)

Lisinopril  Rash  Reaction 0 to 5 Days After Drug  Smooth Plaque

## Update record with new diagnoses and findings

### Recently viewed Diagnoses from VisualDx

Add new Conditions to the problem list

Urticaria  Creutzfeldt-Jakob Disease  Lead Poisoning

## Find patient handouts

### Diagnoses with Patient Handouts in VisualDx

Urticaria

# CDS Hooks Dose Calculator

Prevent ADEs with system-calculated, safe, patient-specific doses

## Med ordering workflow: pediatric patient, sulfamethoxazole/trimethoprim

Baby Girl  
DOB: 05/01/2016  
Age: 5  
Height: 25.00 inches  
Weight: 13.63 kgs  
Gender: Female

mommy.girl@hotmail.com  
855-293-0593  
309-637-4622  
42 Richmond Terrace,  
known, IA, 10301

Common Sigs

**FDB OrderKnowledge Sigs**  
Common ambulatory sigs for sulfamethoxazole 200 mg-trimethoprim 40 mg/5 mL oral suspension

[5 mg/kg] 9 mL by mouth every 12 hours

[150 mg/m<sup>2</sup>] 6 mL by mouth every day; administer 3 consecutive days per week

Source: First Databank  
[First Databank Dose Calculator](#)

**Dosage Calculation: sulfamethoxazole 200 mg-trimethoprim 40 mg/5 mL oral suspen**

Calculated Dosage Amount: Dosage (5 mg/kg) x Patient Weight (13.63 kgs)	68 mg
Rounded Dosage Amount: Not to Exceed:	72.0 mg 160.00 mg
Variance Amount Low: Low variance (0.9 mg) x Calculated Dosage Amount (68 mg)	61.34 mg
Variance Amount High: High variance (1.1 mg) x Calculated Dosage Amount (68 mg)	74.96 mg
Dosing Rounding Increment:	1 mL

Leverages FDB Cloud Connector web services

Calculations happen in real-time using current knowledge base

- See common orders for **this patient** based on their age and the ordered drug
- Smart logic knows this order should be **dosed as trimethoprim**
- Select from **safe** rounded admin amounts

# meducation® (CDS Hooks)

## Meducation Personalized Medication Information

meducation®

Meducation® provides patient-specific medication instructions & regimen summaries at 5-8 grade reading level & 21 languages to reduce errors & improve adherence.

 Interact with Meducation PMI Viewer

## Meducation Regimen Summary

meducation®

Meducation® provides patient-specific medication instructions & regimen summaries at 5-8 grade reading level & 21 languages to reduce errors & improve adherence.

 Interact with MeducationRS

UNIVERSITY MEDICAL CENTER  
University Medical Center  
123 Main Street, Anytown, NC 12345  
212-555-2121  
ID: FHRH7WKJ

EVERY DAY: Medicine you need to use every day.

	Morning	Noon	Evening	Bedtime	
Aspirin Enteric Coated Tablet 81 mg	1				Take by MOUTH. For heart.
Accupril Tablet 10mg	1				Take by MOUTH. For high blood pressure.
Humalog Insulin Solution 100 IU/mL	12 units	14 units	16 units		INJECTION medicine. For diabetes.
Biaxin Oral Suspension 125mg/5 mL	10 mL		10 mL		Take by MOUTH. For infection. Use for 10 days.
Lipitor Tablet 40 mg				1	Take by MOUTH. For high cholesterol.

AS NEEDED: Medicine you should use as needed.

ProAir HFA Inhaler 90 mcg/inh	Use the medicine every 3 to 4 hours. Inhale one to two (1-2) puffs each time.	BREATHING medicine. For asthma attack. Use the medicine as needed for your symptoms.
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If you take any medication that is not on this list, please tell your healthcare provider.



ProAir HFA Inhaler 90 mcg/inh

meducation®

UNIVERSITY MEDICAL CENTER  
University Medical Center  
123 Main Street  
Anytown, NC 12345  
Phone: 212-555-2121

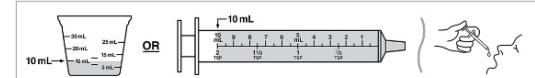
### Biaxin Oral Suspension 125 mg/5 mL

The medicine is used to treat infection.

#### How to take medicine

Take the medicine by mouth twice a day.  
Drink 10 mL each time.

Morning	Noon	Evening	Bedtime
10 mL		10 mL	



Use the medicine for a total of 10 days.

#### Instructions

- Take the medicine with food.
- Keep this medicine at room temperature.
- After using the medicine for the total number of days, throw away any left over medicine.
- It is important that you keep taking each dose of this medicine on time even if you are feeling well.
- If you forget to take a dose on time, take it as soon as you remember. If it is almost time for the next dose, do not take the missed dose. Return to your normal dosing schedule. Do not take 2 doses of this medicine in one time.
- Please tell your doctor and pharmacist about all the medicines you take. Include both prescription and over-the-counter medicines. Also tell them about any vitamins, herbal medicines, or anything else you take for your health.

Ref#: FHRH7WKJ-389785

English  
Biaxin Oral Suspension 125 mg/5 mL



#### Disease Guideline

RxCheck

Hypertension

Medication Options

#### Medication Alert

RxCheck

lisinopril 5 mg tablet

- This medication is not recommended for Black or African American patients.

Switch to amiloride 5 mg-hydrochlorothiazide 50 mg tablet

Optimize pharmacy spend using **actionable recommendations**.

Hypertension + acebutolol 200 mg capsule <small>CMS Triple Weighted</small>	Est. Cost <small>i</small> <b>\$55</b>	Actual Adherence <small>i</small> <b>98%</b>
Seasonal Affective Disorder + Wellbutrin XL (bupropion HCl) 150 mg tablet extended release 24 hr	Est. Cost <small>i</small> <b>\$1,081</b>	Actual Adherence <small>i</small> <b>73%</b>

Improve outcomes through **consistent prescribing**.

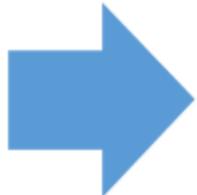
Name	Patients	GDR <small>?</small>	Prescribing Compliance	Prescriptions	High-risk Meds	Total Spend	Potential Savings	Actions
Jamil Miller	52	94%	87%	310	22	\$2,467	\$713	
Darron Durgan	24	98%	76%	279	14	\$3,322	\$616	

Drive performance metrics (e.g., adherence) through **prescribing behavior surveillance**.

# Precision Link at Boston Children's: PGx Recommendations via CDS Hooks

Adjusting medication order based upon genomic data

An **azathioprine** prescription  
based upon a patient's  
expression of **TPMT enzyme**



## Normal metabolizer

### PGx Recommendation

Start with normal starting dose (e.g., 2-3 mg/kg/d) and adjust doses of azathioprine based on disease-specific guidelines. Allow 2 weeks to reach steady state after each dose adjustment.

## Intermediate metabolizer

### PGx Recommendation

If disease treatment normally starts at the "full dose", consider starting at 30-70% of target dose (e.g., 1-1.5 mg/kg/d), and titrate based on tolerance. Allow 2-4 weeks to reach steady state after each dose adjustment.

## Poor metabolizer

### PGx Recommendation

Consider alternative agents. If using azathioprine start with drastically reduced doses (reduce daily dose by 10-fold and dose thrice weekly instead of daily) and adjust doses of azathioprine based on degree of myelosuppression and disease-specific guidelines. Allow 4-6 weeks to reach steady state after each dose adjustment. Azathioprine is the likely cause of myelosuppression.