

2019 IMAGING INFORMATICS SUMMIT



Transforming to Data- Oriented Radiology to Integrate with the Enterprise

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Massachusetts General Hospital

Harvard Medical School

Disclosure

Consultant — Radiology Consulting Group
Advisory Board (travel only) — Siemens

Learning Objectives

- Ways radiology can contribute by becoming more data-oriented in its work output
- Structure of a data-enabled radiology report and how common data elements can help with this
- How assisted reporting frameworks may make it easier for radiologists to work in this new paradigm

Data Divide



Imaging Data

Reason: CHECK ETT TUBE PLACEMENT, ?PNA, CHF
[**Signature 1**]
UNDERLYING MEDICAL CONDITION:
65 y/o male s/p acute MI and catheterization now in CCU with
cardiogenic shock
REASON FOR THIS EXAMINATION:
CHECK ETT TUBE PLACEMENT
?PNA
CHF
[**Signature 1**]
FINAL REPORT
CLINICAL INDICATION: Assess endotracheal tube placement in
patient with congestive heart failure.

Comparison is made to previous study of one day earlier.
An endotracheal tube is present, in satisfactory position.
A Swan-Ganz catheter terminates in the proximal left
pulmonary artery and has been withdrawn in the interval.
An intraaortic balloon pump terminates about 3.3 cm below
the superior aspect of the aortic knob, and a nasogastric
tube terminates in the region of the gastroduodenal
junction.

Cardiac and mediastinal contours are stable in the interval
and pulmonary vascularity is within normal limits for
technique. There has been improvement in the left
retrocardiac opacity and there remains a patchy right
basilar opacification which is slightly increased. A small
amount of fluid is seen in the minor fissure.

IMPRESSION:
1) Lines and tubes in satisfactory position, as detailed
above, with no evidence of pneumothorax.
2) Improved left retrocardiac opacity and worsened right
lower lobe opacity likely due to atelectasis.

JPE
DR. [**First Name1 25**] [**Initials 5**] [**Last Name
26**] Approved: SAT [**13-09-01**] 7:27 PM

Radiology Report

- Lab Values
- Genetic Data
- Diagnoses
- Clinical Measurements
(pulmonary, cardiology)

Clinical Data

The Data Layer



Imaging Data

Reason: CHECK ETT TUBE PLACEMENT, ?PNA, CHF
 [Signature 1**]
 UNDERLYING MEDICAL CONDITION:
 85 y/o male w/ acute MI and catheterization now in CCU with
 cardiogenic shock
 REASON FOR THIS EXAMINATION:
 CHECK ETT TUBE PLACEMENT
 ?PNA
 CHF

Gallbladder/Biliary	
Sonographic Murphy's	Absent
Wall thickening	Absent
Cholelithiasis	Present
Pericholecystic fluid	Absent
Common bile duct caliber	4 mm

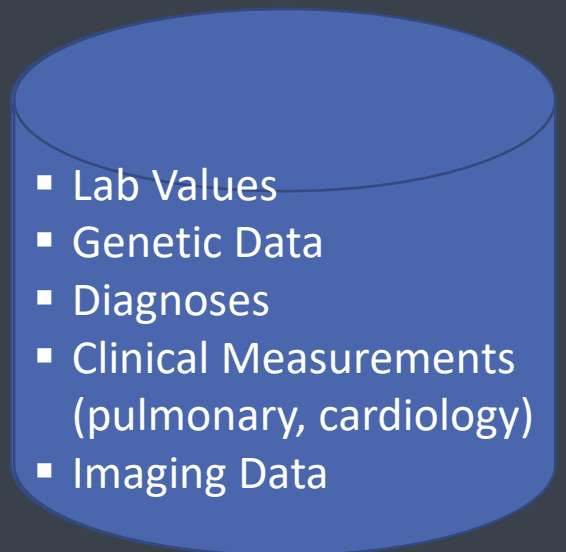
Liver	
Echotexture	Normal
Lesions	None
Intrahepatic biliary duct dilatation	Absent

Right Kidney	
Parenchyma	Normal
Hydronephrosis	None
Calculi	None
Lesions	None
Length	12.5 cm

Left Kidney	
Parenchyma	Normal
Hydronephrosis	None
Calculi	(7 mm, lower)
Lesions	None
Length	11.7 cm

DR. [First Name 1 25**] [Initials S**] [Last Name 26**] Approved: SAT [13-09-01**] 7:27 PM

Data-Enabled Radiology Report
 Radiology Report



Clinical Data

What Kinds of Data?

Measurements

- Lymph node size
- Nodule location
- Liver density
- CBD caliber
- Aorta caliber
- Cobb angle
- PA caliber
- Crown-rump length
- Percent gastric emptying 1 hour

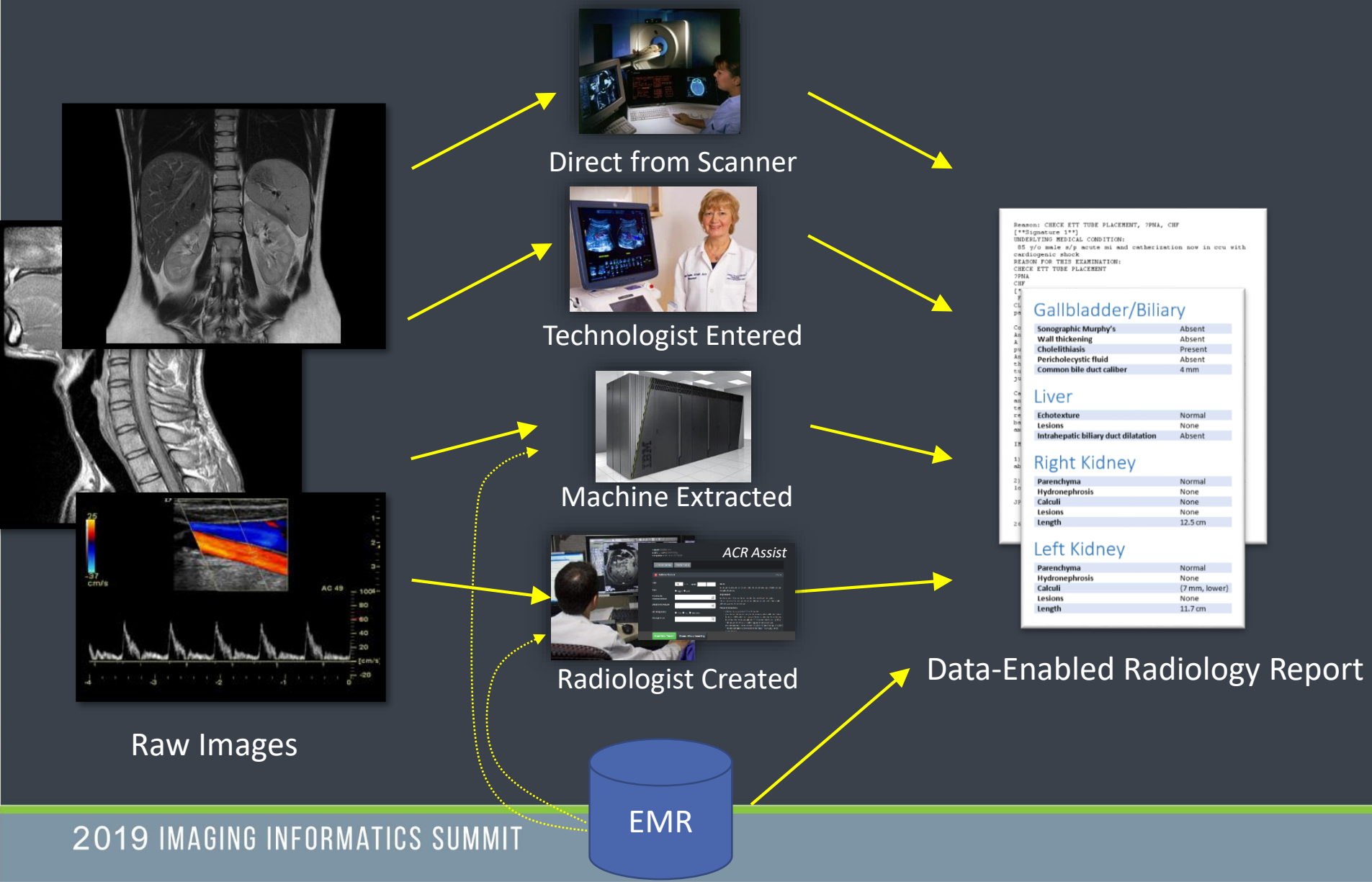
Extractions

- Tumor volume
- Stroke volume
- Hematoma volume
- Percent stenosis
- Liver stiffness
- Gestational age
- Enhancement washout
- Out-of-phase signal dropout
- %LAA-950

Categorizations

- BI-RADS category
- Severity central canal stenosis
- Sonographic Murphy's sign
- Hemorrhage increased in size
- Presence of active extravasation
- Severity of reflux
- Severity of hydronephrosis

Where Does the Data Come From?



Common Data Elements

Features: The elements of a described lesion will be used to determine the output of the algorithm. Includes *synonyms* of those features that might be used in reports.

<algorithm>

```
<features>
  <feature name="size" type="numeric"/>
  <enumeration_feature name="side">
    <choice name="left_side">left</choice>
    <choice name="right_side">right</choice>
  </enumeration_feature>
  <feature name="uniformly_cystic" type="present_absent" default="absent">
    <synonym>fluid density</synonym>
    <synonym>simple cyst</synonym>
  </feature>
  <feature name="density" type="numeric"/>
  <feature name="macroscopic_fat" type="present_absent" default="absent">
    <synonym>fat density</synonym>
  </feature>
</features>
```

- Define attributes associated with the clinical scenario
- Will be labeled with ACR/RSNA Common Data Element (CDE) Identifiers
 - *Ask me... "What's a CDE?"*

Report Data Layer Labeled with CDEs

Report

Patient Data

Order Data

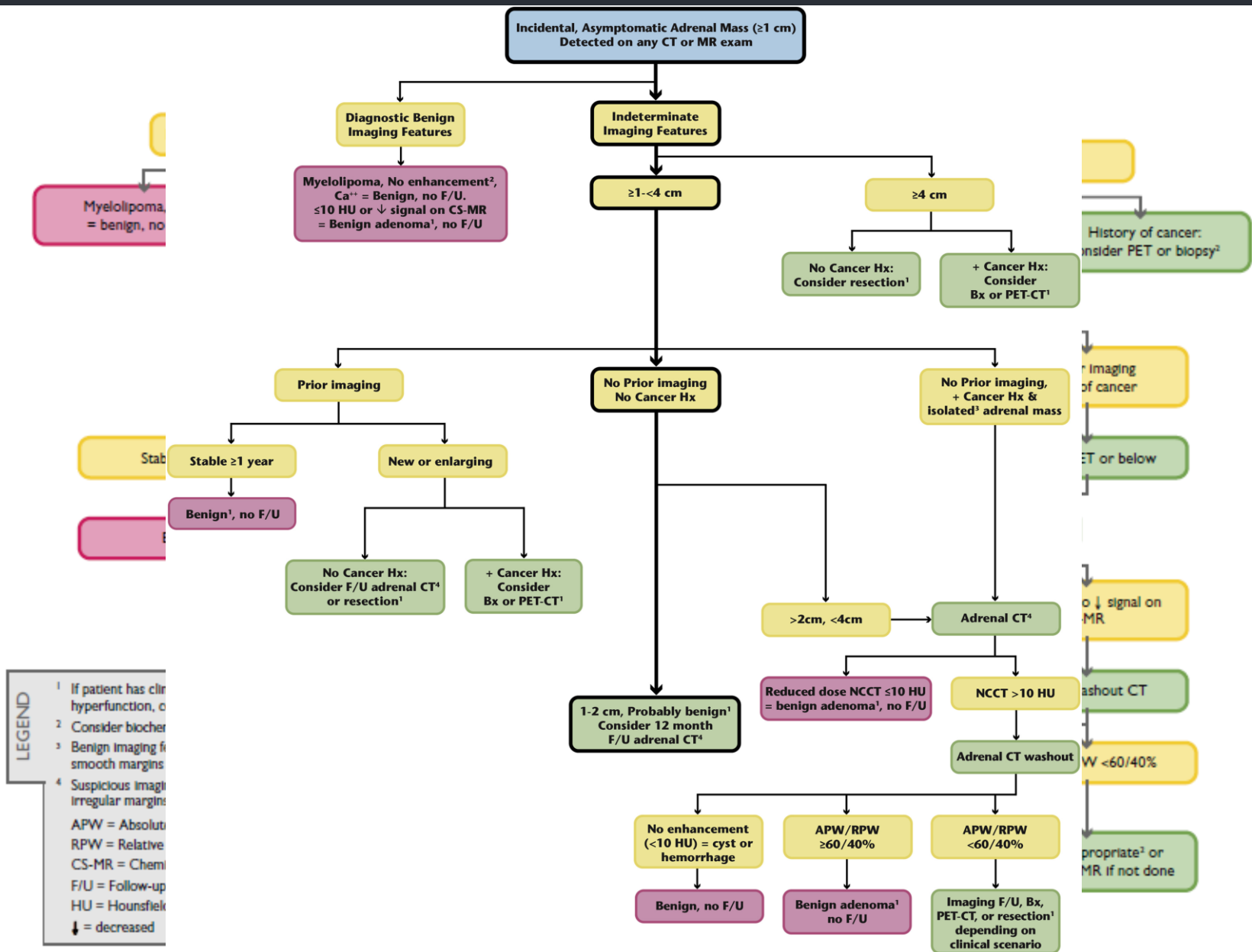
Acquisition
Data

Findings

Finding 1: Adrenal Nodule (RDES 3)

Size (*RDE 41*): 12

Unenhanced
Attenuation (*RDE 43*):
8



Features: The elements of a described lesion will be used to determine the output of the algorithm.

Includes *synonyms* of those features that might be used in reports.

Decision Tree: The logic which determines the output of the algorithm based on a lesion's features.

End Points: Templates of the generated text to be inserted into the body, impression, and recommendations of reports.

<algorithm>

```
<features>
  <feature name="size" type="numeric"/>
  <enumeration_feature name="side">
    <choice name="left_side">left</choice>
    <choice name="right_side">right</choice>
  </enumeration_feature>
  <feature name="uniformly_cystic" type="present_absent" default="absent">
    <synonym>fluid density</synonym>
    <synonym>simple cyst</synonym>
  </feature>
  <feature name="density" type="numeric"/>
  <feature name="macroscopic_fat" type="present_absent" default="absent">
    <synonym>fat density</synonym>
    <synonym></synonym>
  </feature>
</features>
```

```
<decision_tree>
  <if feature="uniformly_cystic" value="present">
    <end_point ref="cyst_no_recommendation"/>
  </if>
  <if feature="hypodense" value="present">
    <if feature="stable" value="present">
      <end_point ref="hypodense_stable"/>
    </if>
    <else>
      <end_point ref="hypodense_no_priors"/>
    </else>
  </if>
  <if feature="macroscopic_fat" value="present">
    <end_point ref="macroscopic_fat"/>
  </if>
  <if feature="old_hemorrhage" value="present">
    <end_point ref="old_hemorrhage"/>
  </if>
</decision_tree>
```

```
<end_points>
  <end_point id="hypodense_stable">
    <body>In the {{side}} adrenal gland{{series_image}}, the previously seen {{size}} mm lesion is homogeneously low density (10 HU or less on non-contrast-enhanced images) and therefore most consistent with an adenoma.</body>
    <impression>{{size}} mm nodule in the {{side}} adrenal gland, similar to prior. Radiologic findings are most consistent with a benign adrenal adenoma.</impression>
    <recommendation>As adrenal adenomas may be hormonally active with subclinical hyperfunction for most patients. Grumbach MM et al. (2003) "Management of the clinically inapparent adrenal incidentaloma," Ann Int Med 138:424-429 and Young, W. (2007) "The incidental discovered adrenal mass," New Engl J Med 356:601-610.</recommendation>
  </end_point>
  <end_point id="hypodense_no_priors">
    <body>In the {{side}} adrenal gland{{series_image}}, the previously seen {{size}} mm lesion is homogeneously low density (10 HU or less on non-contrast-enhanced images) and therefore most consistent with an adenoma.</body>
    <impression>{{size}} mm nodule in the {{side}} adrenal gland, similar to prior. Radiologic findings are most consistent with a benign adrenal adenoma.</impression>
    <recommendation>As adrenal adenomas may be hormonally active with subclinical hyperfunction for most patients. Grumbach MM et al. (2003) "Management of the clinically inapparent adrenal incidentaloma," Ann Int Med 138:424-429 and Young, W. (2007) "The incidental discovered adrenal mass," New Engl J Med 356:601-610.</recommendation>
  </end_point>
</end_points>
```

<algorithm>

Community-owned Schema

Open CAR/DS Framework

Computer-Assisted Reporting/Decision Support

Artifacts

- Schema definition
- Documentation
- Training information
- Reference Implementation

Process

- Subcommittee forming
- Pending release of proposed format
- Anticipate ongoing revisions and additions



ACR Content

- Incidental findings
- *-RADS
- MIPS support

Other Societies

- Fleischner Society
- Society of Radiologists in Ultrasound
- American Society of Neuroradiology

Patient: 74F
Exam: CTABPW (
Completed: 2013-12-02T

Pulmonary Nodule

Adrenal Nodule

× Adrenal Nodule

Size mm Se/Im

Side ☐ Right ☐ Left

Previously characterized

Diagnostic feature

Hx malignancy ☐ Yes ☐ No ☐ Unknown

Changed size

Insert into Report

Close without Inserting

Scans were continued into the pelvis to evaluate the entire GI tract.

COMPARISON: 9/15/2012

FINDINGS:

LOWER THORAX: Lung bases are clear.

HEPATOBIILIARY: No focal hepatic lesions. No biliary ductal dilatation.

SPLEEN: No splenomegaly.

PANCREAS: No focal masses or ductal dilatation.

ADRENALS:

In the right adrenal gland (series 2, image 12), a 12 mm lesion is unchanged in size for at least six months.

KIDNEYS/URETERS: No hydronephrosis, stones, or solid mass lesions.

PELVIC ORGANS/BLADDER: Unremarkable.

PERITONEUM / RETROPERITONEUM: No free air or fluid.

LYMPH NODES: No lymphadenopathy.

VESSELS: Unremarkable.

GI TRACT: No distention or wall thickening.

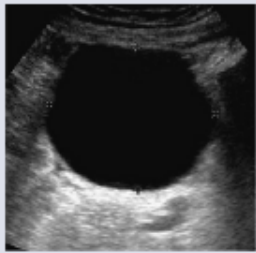
BONES AND SOFT TISSUES: Unremarkable.

IMPRESSION:

Stable 12 mm right adrenal nodule. Radiologic findings are most consistent with a benign adrenal adenoma.

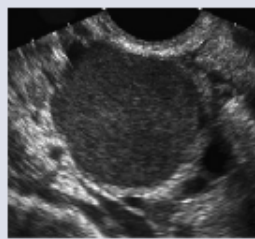
RECOMMENDATION:

As adrenal adenomas may be hormonally active with subclinical features, NIH guidelines suggest further evaluation for endocrine hyperfunction for most patients. Cf. Grumbach MM et al. (2003) "Management of the clinically inapparent adrenal mass ('incidentaloma')," Ann Int Med 138:424-429 and Young, W. (2007) "The incidentally discovered adrenal mass," New Engl J Med 356:601-610.



- Round/oval
- Anechoic
- Smooth/thin walls
- Post. enhancement
- No internal flow

Simple Cyst



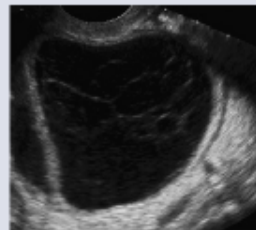
- Homogeneous, low-level echoes
- No solid component
- \pm Tiny mural echogenic foci

Endometrioma



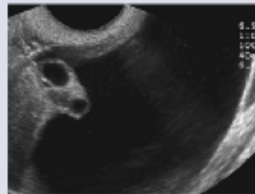
- Focal or diffuse hyperechoic component
- Hyperechoic lines/dots
- Acoustic shadowing
- No internal flow

Dermoid



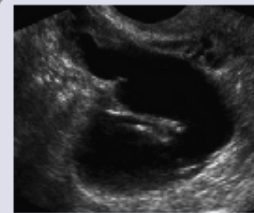
- Reticular echoes
- \pm Solid-appearing region w/concave margin
- No internal flow

Hemorrhagic Cyst



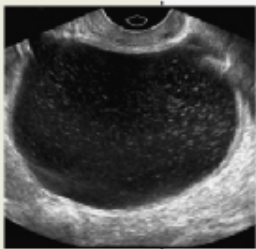
- Follows contour of adjacent organs
- Ovary at edge/suspended in mass
- \pm Septations

Peritoneal Inclusion Cyst



- Tubular, cystic
- \pm short, round projections
- \pm "Waist" sign
- \pm separate from ovary

Hydrosalpinx



Findings suggestive of, but not classic for, hemorrhagic cyst, endometrioma, or dermoid.

Suggestive of

Hem Cyst Endm'oma Dermoid



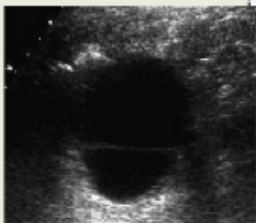
Septations <3mm

Multiple Thin Septations



Septations >3mm or irregular.

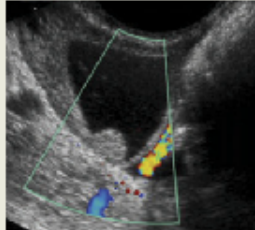
Thick Irregular Septations



Thin-walled cyst with single thin septation or focal calcification in the wall of a cyst

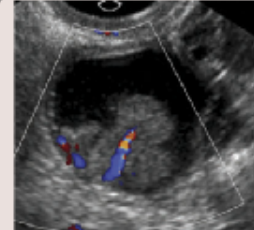
Simple Cyst with

Single Septa Focal Calc



Non-hyperechoic nodule without vascularity

Nodule Without Flow



Non-hyperechoic nodule without vascularity

Nodule With Flow

**TECHNIQUE:**

Transabdominal and transvaginal ultrasound imaging of the pelvis was performed.

COMPARISON: [None available]

FINDINGS:

KIDNEYS: [Unremarkable]

UTERUS: The uterus measures [8.3 cm]. The endometrial echocomplex measures [6 mm].

OVARIES/ADNEXA: [A lesion is seen in the left ovary measuring 3 cm with appearance consistent with hemorrhagic cyst]

PELVIS: [No] free fluid.

IMPRESSION:

[A hemorrhagic cyst in the left ovary. Follow-up pelvic ultrasound is recommended in 6-12 weeks in an early post-menopausal woman. Optimally, the exam would take place in the follicular phase, days 3-10, of the menstrual cycle]

Recommendations for adnexal cyst follow-up per Society of Radiologists in Ultrasound 2009 consensus statement on management of asymptomatic and ovarian and other adnexal cysts (Levine et al., Radiology 2010 256: 943-54).

+ Create your own module

Search...

Assist Modules

115

Hello Assist 3

Hello RADS 1

Adrenal CT 1

LI-RADS 73

Lung RADS

TI RADS

IF-Pituitary FDG-PET 1

IF-Pituitary CT MRI 3

PI RADS 16

NI-RADS 17

IF-Liver

IF Thyroid CTMRIUS

IF Thyroid FDGPET

CDE Modules

4

Scenarios

Metadata

Data Elements

Report Text

Sync RadElements

Simulator

XML View

Key Images

Reset

Observation in high risk patient *

Select one

Arterial phase enhancement *

Select one

Hypo-enhancement

Iso-enhancement

Hyper-enhancement

Diameter (mm) *

Washout *

Yes ☐ No

OR

Not sure? try out this image



Capsule *

Yes ☐ No

OR

Not sure? try out this image



Threshold Growth (mm) *

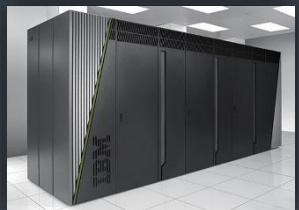
Yes ☐ No

OR

Not sure? try out this image



Next-Generation Radiology Reporting



Reason: CHECK
[Signature]
UNDERLYING RE
55 y/o male
cardiac and
REASON FOR THE
CHECK ETT TUB
TUBA
CSP
[Signature]
FINAL REPORT
CLINICAL INDIC
patient with

Comparison is
An endotrache
A Semi-Gans
pulmonary act
An intracran
the superior
tube termin
junction.

Cardiac and m
and pulmonar
technique. T
retrocardiac
basilar opac
amount of flu

IMPRESSION:
1) Lines and
above, with n
2) Improved
lower lobe op

JPE
DR: [Signature]
26**] Approved

Gallbladder/Biliary	
Sonographic Murphy's	Absent
Wall thickening	Absent
Cholelithiasis	Present
Pericholecystic fluid	Absent
Common bile duct caliber	4 mm

Liver	
Echotexture	Normal
Lesions	None
Intrahepatic biliary duct dilatation	Absent

Right Kidney	
Pararenchyma	Normal
Hydronephrosis	None
Calculi	None
Lesions	None
Length	12.5 cm

Left Kidney	
Pararenchyma	Normal
Hydronephrosis	None
Calculi	(7 mm, lower)
Lesions	None
Length	11.7 cm

Recommendation	
Exam	Abdominal US
Indication	Liver lesion
Timeframe	5-7 months
Alternative Exam	Liver MRI

Data Context



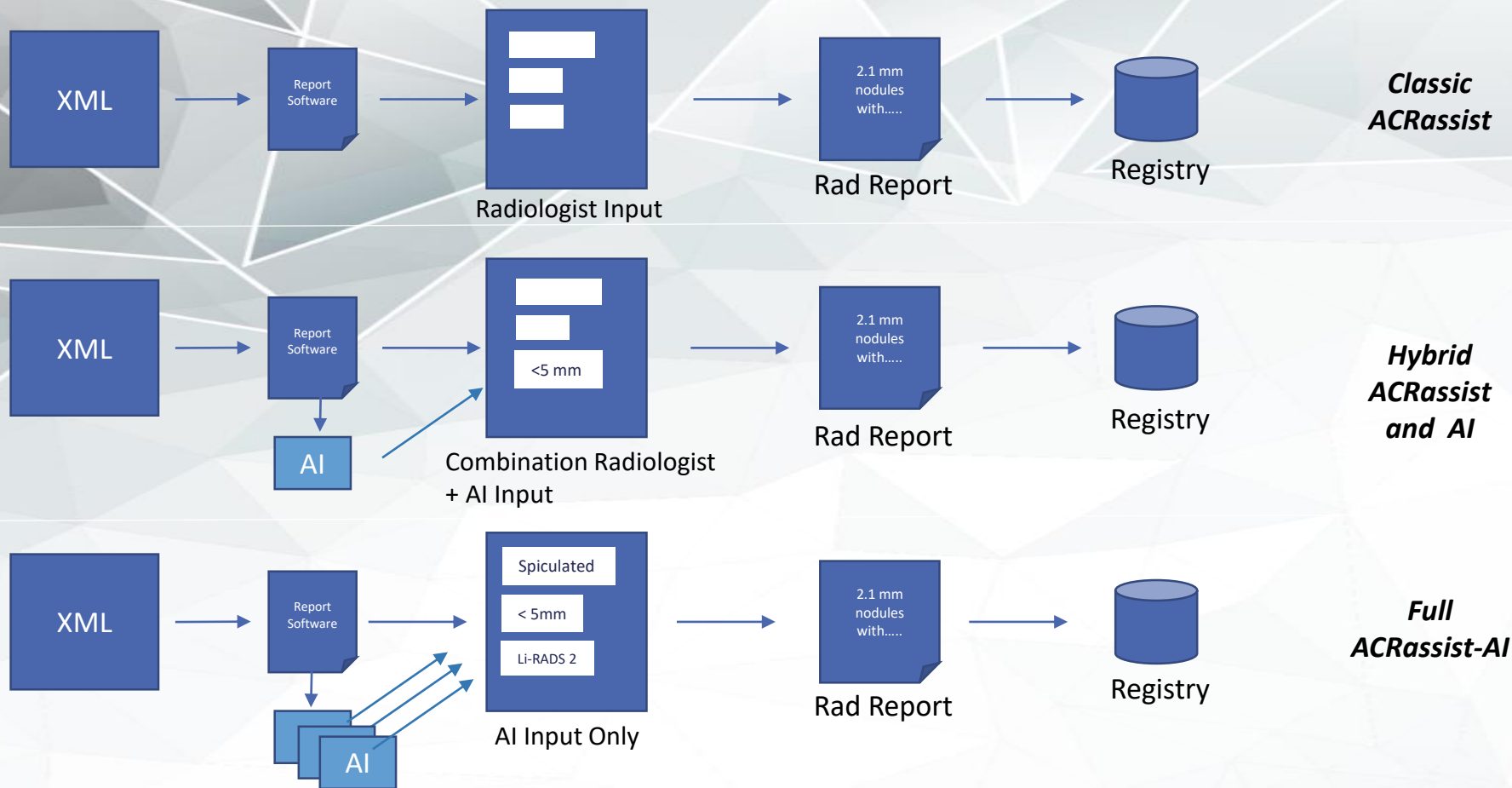
EMR



Registries

Data-Enabled
Reporting Environment

AI-Enabled Decision Support

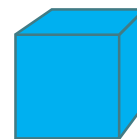
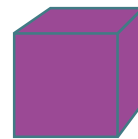
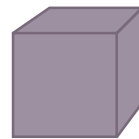
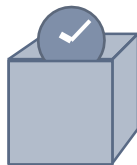
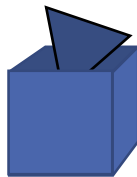
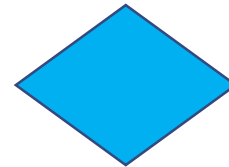
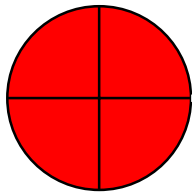


Decision Support and AI

- CAR/DS Modules define data elements
 - Labeled and registered as Common Data Elements
- CAR/DS can be used for some data annotation
- CAR/DS modules provide a target for integration
- Output from use of CAR/DS modules can feed back onto modules for further improvement

Structured Recommendation

“Regarding **ITEM**, recommend **ACTION** in **TIME** for **REASON** with **STRENGTH** pending **DEPENDENCY**.”

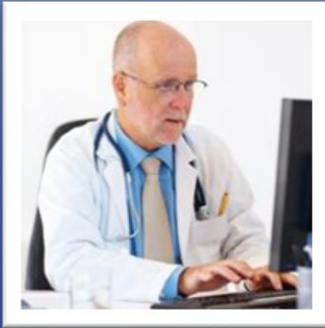


Structured Recommendation

In low or average risk patients, the hepatic finding is most likely benign and no additional follow-up is warranted. In high risk patients, this finding remains indeterminate for a neoplastic process and follow-up CT or MRI in 6 months is recommended.

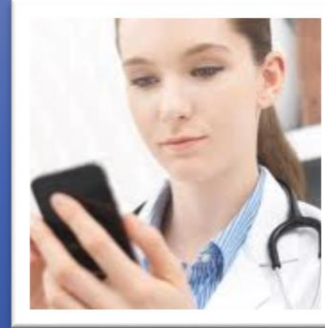
```
<EndPoint Id="smallUnknownRisk">
  <Label>CT or MRI in 6 months if high risk</Label>
  <ReportTexts>
    <ReportText SectionId="body">A <InsertValue DataElementId="size" /> mm lesion is seen <InsertPartial PartialId="locationText" />
    <ReportText SectionId="impression">A <InsertValue DataElementId="location" /> hepatic lesion measuring <InsertValue DataElementId="size" /> mm
    <ReportText SectionId="recommendation">In low or average risk patients, the hepatic finding is most likely benign and no additional follow-up is warranted. In high risk patients, this finding remains indeterminate for a neoplastic process and follow-up CT or MRI in 6 months is recommended.
    <ReportText SectionId="impressionRecommendation">A <InsertValue DataElementId="location" /> hepatic lesion measuring <InsertValue DataElementId="size" /> mm
  </ReportTexts>
  <ImagingFollowup>
    <ClinicalCondition>Patient is high risk</ClinicalCondition>
    <EvidenceLevel CodingSystem="OCEBM2011">Level 5</EvidenceLevel>
    <PreferredImagingExam Code="RPID5">CT ABDOMEN WITH IV CONTRAST</PreferredImagingExam>
    <AcceptableImagingExams>
      <Exam Code="RPID474">MR ABDOMEN WITHOUT THEN WITH IV CONTRAST</Exam>
      <!-- Many more go here -->
    </AcceptableImagingExams>
    <IndicationForFollowup CodingSystem="ICD-10" Code="R93.2">Abnormal findings on diagnostic imaging of liver and biliary tract</IndicationForFollowup>
    <RecommendedTimeFrame Earliest="P165D" Latest="P210D"/>
  </ImagingFollowup>
</EndPoint>
```

Benefits of Structured Recommendations



Ordering

One-click response to order recommended exam(s).



Tracking

Identify when recommended exam hasn't been obtained.



Responding

Cue radiologist reading recommended exam to respond.



Monitoring

Track rates of recommendation, compliance, and outcomes.

Imaging Driven Care Pathways

2. **Data Extraction:**
Generate usable
structured
data from images

4. **Data-oriented Reporting:**
Focused on structuring key
output data elements
based on clinical scenario

Data-Driven Image Acquisition

- Identify
- as
- Dynamic
- De
-
-

Data-Assisted Interpretation

- Incorporates EMR data and extracted data
- Hyper-dynamic hanging protocols
- Identify/separate anatomic structures
- Flag potential findings
- Identify/demonstrate findings on prior exams for comparison

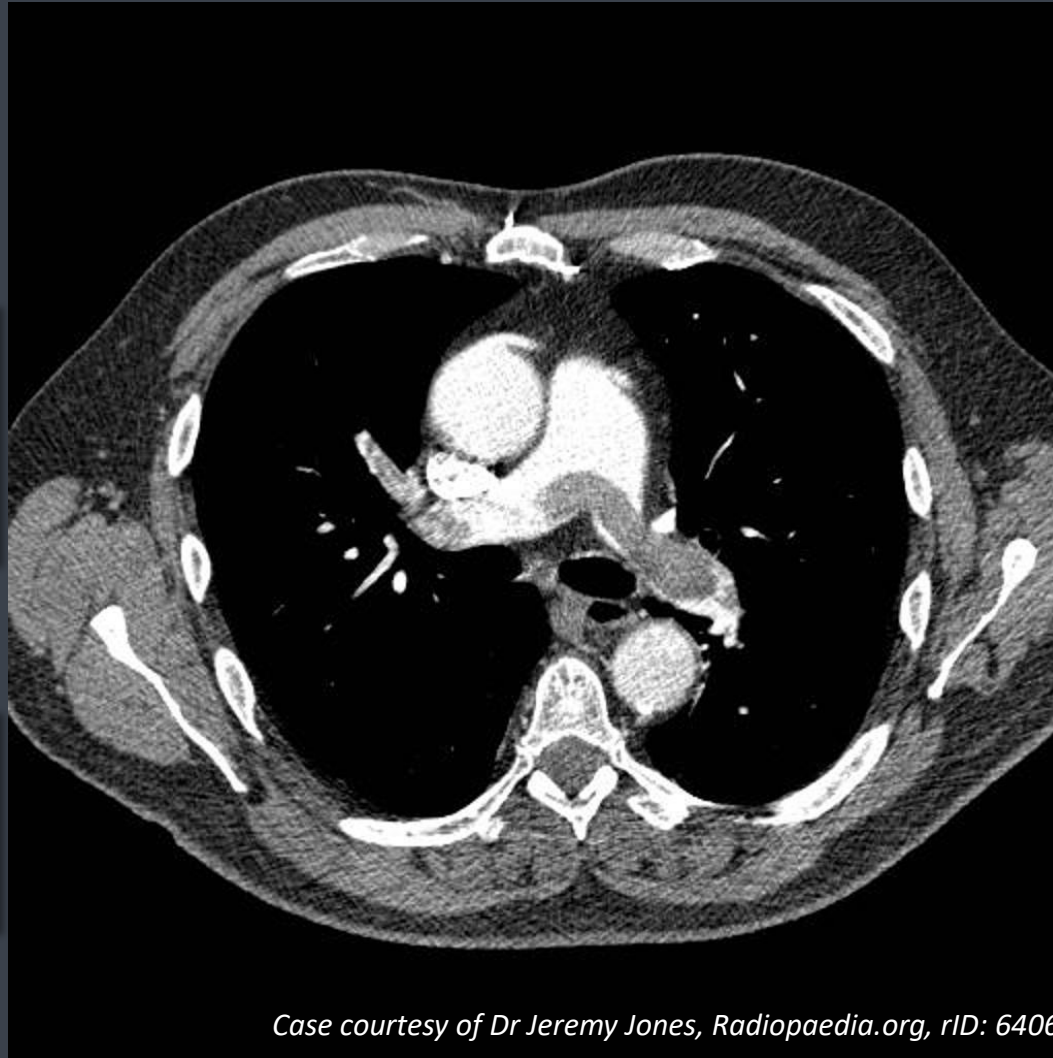
1. **Image Acquisition:**
Image protocols tailored
to extract needed elements

3. **Data-assisted Interpretation:**
Build data context with clinical questions, clinical
data, image views, findings, measurements.

EMR

Treatment Guidance:
Incorporate logic
based on imaging,
other clinical data

Imaging Driven Care Pathway Example



1. Image Acquisition

Optimize imaging parameters for data extraction

3. Data-oriented Interpretation

Visualize candidate emboli
Demonstrate septum, reflux

5. Treatment Guidance

Discharge *or*
Anticoagulate *or*
Thrombolyse *or*
Order TTE *or*
Consult surgery

Radiology in the Enterprise

- Work more oriented to driving downstream decisions
 - Salient question
 - Rest of the story
- Incorporate more upstream data sources
 - Imaging-based AI
 - Other data science tools
- Demonstrable value proposition

