Design FHIR Structured Reporting Template for Breast Image Exam

Abstract

This research plans to improve radiologists' performance in practice by designing a FHIR structured reporting template for breast image exam. The structured report can be used to describe image annotation, image finding, and clinical report. This paper proposes a FHIR solution for recording annotations, findings, and clinical report. According to the specifications of FHIR standard resources (observation and diagnosticReport), the annotations, findings, and clinical report would be XML formatted and could be stored in FHIR server. The FHIR-based annotations could be referenced by FHIR-based image findings and diagnostic reports. Using HL7 FHIR to integrate structured reporting reports will bring much more advantage for radiologist in performing their tasks. It is convenient for sharing the reports among radiologists, and also it can be helpful integrating with AI systems in the future. Additionally, conversion of clinical report from English to Chinese or Indonesian language will be more convenient, since each FHIR element in the resources the values are structured and terminologies are standardized coded. This would be convenient, for converting FHIR XML formatted report to different language report results that would be easily understudied by patient.

Background

Breast Mammography Report
Observer: Dr.xxx
History: -
Findings:
- Finding: Mass in one side of breast
- Best illustration of findings:

Conclusions:
- Conclusion: Mass

Diagnosis Codes:
- Diagnosis: 172.9/ICD9

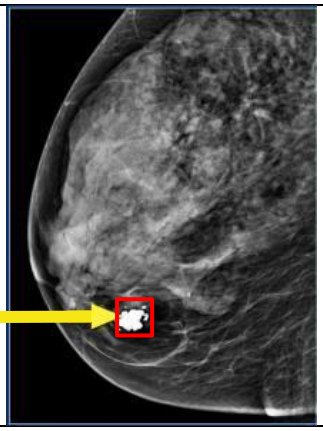


Figure 1. The simple example of traditional plain text Report

Figure 1 left side content illustrates plain text report that written by radiologist. However, using the plain format would be difficult for the integration in the future and also for further analysis. And theoretically, the image finding needs to be further described, such as its position, size, margin, shape, and also refers to the annotation. But the traditional reporting system doesn't have this functionality.

It makes radiologists hard to analyze the clinical report. Radiologists diagnose whether the result is benign or malignant based on the image finding and their own experience. The correctness of the diagnostic result depends on the clear references information written in the description of the image finding.

About 20 years ago, after the introduction of XML, the traditional reports are converted into XML or JSON format. There are many XML or JSON documents form tree structures to describe X-ray reports, breast ultrasound report, and breast mammography report. In DICOM SR (Digital Imaging and Communications in Medicine Structure Report), all content items are encoded as a single tree with a single "root" content item. The root conveys the "document title." Meanwhile its children and their descendants convey the content of the document. A SR may be as simple as a "flat" list of content items below the document title and may be as complex as a directed acyclic graph (DAG). The DAG structure is illustrated in the example shown in Figure 2.

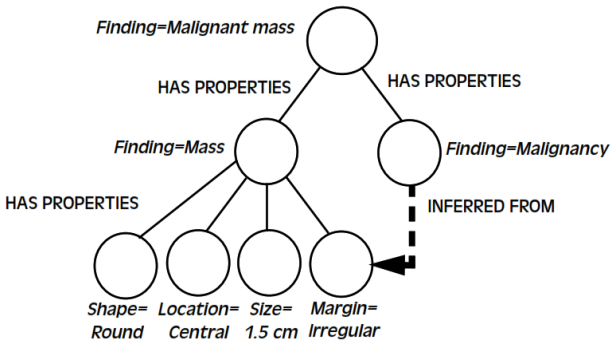


Figure 2. A DICOM SR tree with references

As shown in figure 2, the finding found is a mass type. The mass type will refer to the nodes below it. Those nodes are the description of the finding, including the annotation, shape, location, size, and margin. After discovering the mass, which then undergoes further inspection, with malignancy as the inspection result. Malignancy is found based on some parameters, such as the shape of the margin or the analysis of the other measurement.

Discussion of Literature Review

As DICOM aims to develop standards for documents that incorporate references to images and associated data. SR was added to the DICOM standard at the beginning of year 2000. Structured data, analytic results and clinical observations made in the imaging environment were standardized with SR, extending DICOM beyond just images.

The conventional DICOM SR is a structured report described in DICOM format. The ability to "collect" references to different types of object into a single persistent document is possible in DICOM SR. However, the conventional DICOM specifications are quite complicated. Because it needs to be packaged as a single and complicate DICOM, which makes it hard to decode and encode by system developer. The other problem is that DICOM requires too much knowledge which makes it difficult to understand. According to DICOM standard, the annotation should be DICOM SR or Presentation State (PS) formatted for storing into DICOM web server. The DICOM objects are too complicated to handle by image viewing and reporting systems. It would be a great challenge for system developers for handling SR or PS DICOM objects and designing a general purpose image viewing and report creating system.

This paper suggests using FHIR structured report for breast image exam. FHIR structured report is in XML or JSON formatted, it can be used to describe image annotation, image finding, and diagnostic report. Many of the defined elements in a resource are references to other resources. Using these references, the FHIR-based annotations could be referenced by image findings and findings could be referenced by diagnostic reports, which illustrated as figure 3.

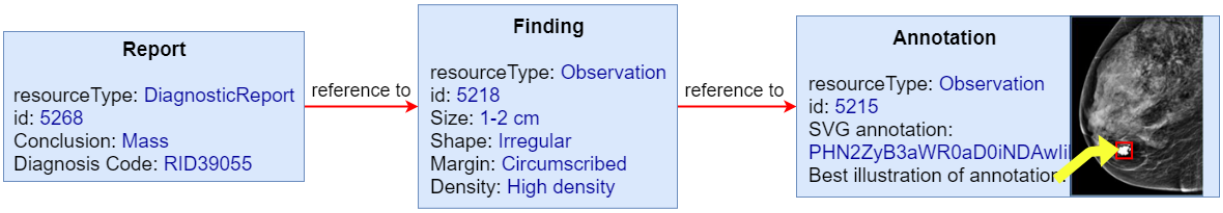


Figure 3. Illustration of FHIR references concept

Information systems require processing and analysis, including current AI systems. The transformation from DICOM to FHIR structured report with the expectation that computer will be easier to process in the future. It will be easier to find some information for the purpose of breast image exam analysis. It is convenient to have a FHIR structured report, especially in the application of AI medical imaging system.

Method

Currently, there exists a wide variety of tools and technologies to diagnose breast cancer. If cancer is detected, the image exam result can help doctors to find the type of cancer, as well as determine the stage and location of the cancer. The latest breast imaging modalities, including the mammography, ultrasound, and MRI. Mammography is the use of X-ray to create images of the breast. Breast ultrasound is an imaging modality that uses ultrasound waves to create images of breast tissue. Meanwhile, MRI can provide the clearest, most detailed pictures of the breast.

No matter which kinds of screening technology used, the clinical result will be written in a report. Breast image report mainly contains three parts, which are annotation, finding, and report. Annotation used to mark up some regions that can be used to represent abnormal findings. Meanwhile for the explanation of finding, if radiologist found something abnormal in the medical image of breast, it means a finding. Report is the final result which state whether the result is benign or malignant.

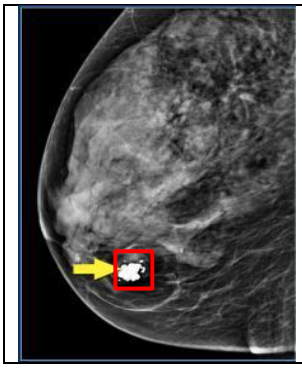
FHIR Solution for Medical Image Annotation, Finding, and Report

As we explained earlier, FHIR structured report can be used to describe annotation, finding, and report. In this proposal we show a FHIR solution for recording annotation, finding, and report.

Annotation resource type: FHIR observation
Finding resource type: FHIR observation
Report resource type: FHIR diagnosticReport

As demonstrated in figure 3, FHIR diagnosticReport.result would reference to findings (observations). And image finding (observation.derivedFrom) would reference to another observation that contains annotation data on a specific medical image.

1. Annotation



SVG annotation example:

```
<svg width="400" height="450" >
<rect x="1344" y="2410" width="204"
height="207" style="stroke:rgb(255,255,0);
stroke-width:2; fill:none " /></svg>
```

Base 64 conversion result:

PHN2ZyB3aWR0aD0iNDAwIiBoZWlnaHQ9IjQ1MCI+CjxyZWN0IHg9IjEzNDQiIHk9IjI0MTAiIHdpZHRoPSIyMDQiIGhlaWdodD0iMjA3IiBzdHlsZT0ic3Ryb2tlOnJnYigyNTUsMCwwKTtzdHJva2Utd2lkdGg6MiIgLz48L3N2Zz4=

Figure 4. SVG annotation for medical image

- SVG Medical Image Annotation

As demonstrated in figure 4, a Scalable Vector Graphics (SVG) rectangle is presented on a mammography image. The medical images were stored in DICOMWeb server. And the images can be accessed through DICOM WADO protocol. A web base image viewer can use JavaScript to access the image that stored in DICOMWeb server. We can also make annotation on the image by our viewer. However, the annotation would not be stored into DICOMWeb server.

This paper suggests using W3C SVG to store medical image annotations. SVG is a XML-based vector image format for two-dimensional graphics. SVG specifications have clear defined geometric graphics, such as line, ellipse, etc. We can create a simple SVG webpage that links to WADO image and contains geometric graphic annotation as demonstrated in following example:

```
<html><body><svg width="400" height="450" >
<image x="0" y="0" width="400" height="450" xlink:href=
  "https://DICOMWebServer.WADO/studies/1.2/series/3.4/instances/5.6"/>
<rect x="1344" y="2410" width="204" height="207"
  style="stroke:rgb(255,255,0); stroke-width:2; fill:none" />
</svg></body></html>
```

Example 1. SVG web page with DICOMWeb image and a rectangle graphic

Example 1 is a WADO image and would be jpg formatted as the default WADO response result format specified in DICOM standard. And <rect x="1344" y="2410" width="204" height="207" style="stroke:rgb(255,255,0); stroke-width:2; fill:none" represent a rectangle that has 2 pixel width yellow border. SVG standard has richful graphic specifications supported by most browsers. Consequently, we can open example 1 by IE, Chrome, or Firefox that would have the same result as that presented in figure 4. However, the SVG annotation and WADO image might also be presented in an application based viewer. The self-developed viewer might not have the browser that support all SVG specifications defined in W3C. We must confine a subset of W3C SVG specifications that have simple and enough geometric graphics and styles that can be easily supported by viewers.

- FHIR Observation that Contains SVG Annotation

We suggest that the SVG annotation would be contained in FHIR observation and be stored in FHIR server. The FHIR observation.valueString may be used for storing annotation information. However, FHIR observation should be XML or JSON formatted. And W3C SVG graphics should be XML formatted. If we put SVG data directly into XML or JSON FHIR observation.valueString that would cause error when we upload the annotation observation to FHIR server. To solve the problem, we suggest that the SVG data should be base64 encoded as demonstrated in figure 4. Consequently, we could put the SVG data into FHIR observation and upload the result to FHIR server. The FHIR annotation observation is demonstrated in Example 2.

```
{"resourceType": "Observation","status": "final",

"code": {"coding": [ {"system": "https://www.dicom.org.tw/SVG","code":
"SVG.Annotation","display": "SVG Annotation"}]},

"focus": [ {"reference":
"https://DICOMWebServer.FHIR/ImagingStudy/imgSTDid4567_SOPInstanceUIO5.6"}],

"valueString":"PHN2ZyB3aWR0aD0iNDAwIiBoZWlnaHQ9IjQ1MCI+"}
```

Example 2. SVG base64 annotation contained in FHIR Observation.valueString

Example 2 is a simple FHIR image annotation. The annotation data is base64 encoded and stored in FHIR observation.valueString. Decode the base64 string will restore SVG annotation data as that shown in figure 4. The FHIR observation has been uploaded to a FHIR testing server and can be access at following URL: https://hapi.fhir.tw/fhir/Observation/5215

In example 2, observation.Focus reference to an URL that points to a DICOMWeb server. The URL was created according to FHIR reference data type requirement. Therefore, the observation can be stored into FHIR server without errors.

2. Finding

As presented in figure 3, the annotation (FHIR observation) can be referred by image finding (another FHIR observation). This proposal will use breast ultrasound case as an example to describe more thoroughly about image finding. In the case of breast ultrasound, image finding have 4 types, which are mass, calcifications, focal asymmetry, and architectural distortion. Each type of lesion has its own code and represent a finding. And each lesion is represented by an Observation Resource. Below is the example of FHIR Observation that contains Mass type finding.

Image Finding in FHIR Observation (Mass type finding)

```
{
"resourceType": "Observation",
"id": "5218",
"derivedFrom": [{"reference": "Observation/5215"}],
"component": [
{"code": {"coding": [{ "system": "http://misat.org.tw/CodeSystem/SizeCS",
"code": "SO2","display": "1-2 cm"  }]}},
{"code": {"coding": [{"system": "http://misat.org.tw/CodeSystem/ShapeCS",
"code": "SO4","display": "Irregular"  }]}},
{"code": {"coding": [{"system": "http://misat.org.tw/CodeSystem/MarginCS",
"code": "MO1","display": "Circumscribed"  }]}},
{"code": {"coding": [{"system": "http://misat.org.tw/CodeSystem/DensityCS",
"code": "HD","display": "High-density"}]}}  ]
}
```

Referenced to the FHIR annotation

The FHIR observation can be access at following URL:https://hapi.fhir.tw/fhir/Observation/5218

This is an example of mass type finding. The value of "derivedFrom" object reference to the FHIR observation resource which contains the finding's annotation. Meanwhile the value of the "component" object contains finding's description such as the location, margin, size, density, and the other.

3. Diagnostic Report

After all findings have been written into its own type of lesion, radiologists need to complete the diagnostic report. It contains one report and multiple findings. The diagnosticReport which consists of the entire inspection data after a certain medical visit will be uploaded to the FHIR server in diagnosticReport resource type.

```
{"resourceType": "DiagnosticReport",
"id": "5268",
"status": "final",
"result": [
{"reference": "Observation/5218"},
"identifier": {"system": "http://www.radlex.org","value": "RID39055"}},
{"identifier": {"system": "http://www.radlex.org","value": "RID49972_Right"}},
{"identifier": {"system": "http://www.radlex.org","value": "RID34317_Right"}}],
"conclusion": "4"}
```

Referenced to the mass type finding

The FHIR diagnosticReport can be access following URL:
https://hapi.fhir.tw/fhir/DiagnosticReport/5268

Expected Result

The anticipated outcomes of this proposal are summarized in table below.

Time	Explanation
2020/07 -2020/09	The proposal will be coordinated with 台灣醫療影像資訊標準協會 (MISAT, Medical Image Standards Association of Taiwan) MI-TW connectathon, for testing interoperability with FHIR server and another FHIR image viewer developed by another vendors
2020/10 - 2020/12	Find a professional radiologist to set up the detail specification of breast report findings and annotations
2021/01	Demonstration of FHIR breast system in RSROC (Radiological Society of the Republic of China)

The FHIR report system contains two parts, which are report creator and report viewer. We have preliminary produce the web viewer (figure 5) based on our previous paper and report template (figure 6), but these specifications may not be very clear. Currently, it does not meet the actual application. The actual application should be discussed more thoroughly. In the future, it may be possible to create a reporting system based on the above-mentioned FHIR specifications.

A. Report Creator

Report creator emphasize on the image finding part. After the annotation is marked on the image, then radiologist will describe the finding.

- Image viewer and FHIR annotation

In the web-based image viewer, we can see the images and mark annotation on the image.

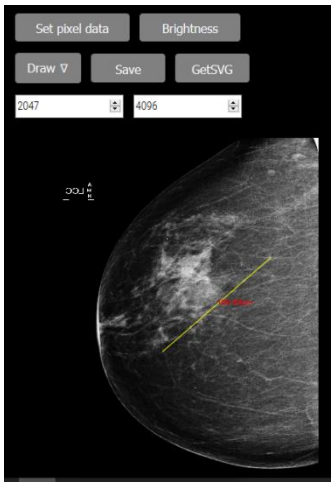


Figure 5. Medical Imaging Web Viewer

SVG Conversion of a Line

<svg width="400" height="450">

<line x1="1241" y1="2085" x2="2163" y2="1161" style="stroke:rgb(255,0,0);stroke-width:2" />

</svg>

- Finding HTML template

If ultrasound is performed for evaluating clinical signs and/or finding on imaging modality, the indication for the examination and finding(s) should be referred to in the report.

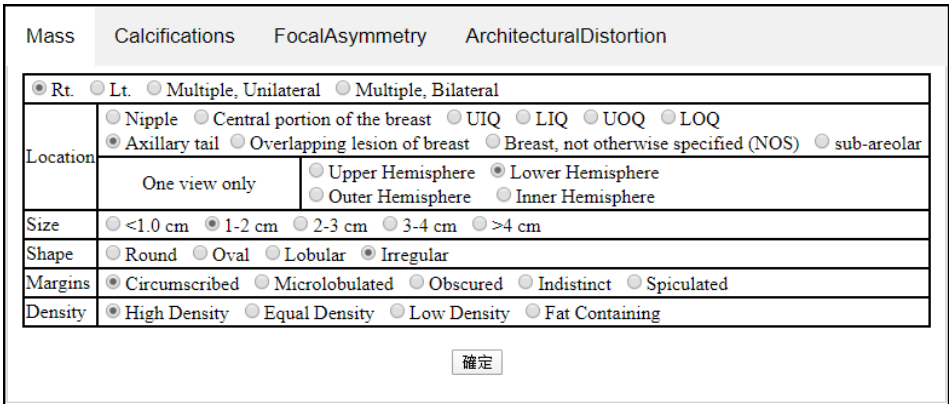


Figure 6. Image finding in the type of Mass

B. Report Viewer

The breast mammography screening case discussed earlier, i.e., based on the report creator, a FHIR diagnostic report will be generated. The diagnostic report also contains finding and annotation. The following example is an example of a diagnostic report which encoded as narrative text only:

MG Breast Screening	
Patient's reference	Patient/89
serviceRequest's reference	ServiceRequest/1570
Practitioner's reference	Practitioner/11
Encounter's reference	Encounter/1573
Status	FINAL
Issued	28 November 2019
Finding's reference	Observation/5218
Conclusion	BIRAD 4 (Suspicious Abnormality – Biopsy should be considered)

Figure 8. Report viewer in English language version

There are related techniques in this example. The original report can be turned into an English version report, where the layout result is much more convenient for doctors and patients to see. The report can also be translated into Chinese or Indonesian version of report.

References

https://stanfordhealthcare.org/medical-tests/b/breast-imaging/types.html
https://www.dicomstandard.org/history/
https://radiologyassistant.nl/breast/bi-rads-for-mammography-and-ultrasound-2013
http://www.dclunie.com/pixelmed/DICOMSR.book.pdf
https://id.scribd.com/doc/314121704/Form-Deteksi-Dini-IVA-SADANIS
https://www.hl7.org/fhir/diagnosticreport.html
https://www.hpa.gov.tw/Pages/Detail.aspx?nodeid=876&pid=4888
https://wiki.hl7.org/Imaging_Integration_WG
http://hl7.org/fhir/us/breastcancer/2018Sep/
https://www.rsroc.org.tw/annual/

Advices from Professor

- Find some experts to evaluate this proposal and give some feedbacks that would be useful in improving this study
- The requirements of knowledge about FHIR and DICOM Web standard
- Security requirement of FHIR report system
- Contact professional radiology personnel especially who specialize in breast screening to discuss the report specification for further standardization along with the real practice and long-term development of its own personnel