

MODERN
RADIOLOGY
eBook

Medical Imaging Informatics

ESRF EUROPEAN SOCIETY
OF RADIOLOGY



/ Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the *ESR eBook* with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the *ESR eBook* was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to 'dig deeper'. As a result, *Modern*

Radiology covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the *ESR eBook* across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an *ESR eBook*, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this *educational* tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor

Professor of Radiology, University of Geneva, Switzerland

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Copyright and Terms of Use

This work is licensed under a [Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License](#).

You are free to:

Share, copy and redistribute the material in any medium or format

Under the following terms:

/ **ATTRIBUTION** – You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

/ **NONCOMMERCIAL** – You may not use the material for commercial purposes.

/ **NODERIVATIVES** – If you remix, transform, or build upon the material, you may not distribute the modified material.

How to cite this work:

European Society of Radiology, Emmanouil Koltsakis, Marcio Aloisio Bezerra Cavalcanti Rockenbach, Merel Huisman, Pinar Yilmaz, Tugba Akinci D' Antonoli, Vera Cruz e Silva, edited by: Elmar Kotter, Erik R Ranschaert, Merel Huisman, Peter M.A. van Ooijen (2025), ESR Modern Radiology eBook:

/ Medical Imaging Informatics.

DOI [10.26044/esr-modern-radiology-30](https://doi.org/10.26044/esr-modern-radiology-30)

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Signage

 **CORE KNOWLEDGE**

 **ATTENTION**

 **Hyperlinks**

 **FURTHER KNOWLEDGE**

 **COMPARE**

 **REFERENCES**

 **QUESTIONS**

 **Medical Imaging Informatics**

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge



Based on
the ESR
Curriculum for
Radiological
Education

Medical Imaging Informatics

EDITORS

Elmar Kotter | Erik R Ranschaert | Merel Huisman | Peter M.A. van Ooijen

AUTHORS

Emmanouil Koltsakis | Marcio Aloisio Bezerra Cavalcanti Rockenbach | Merel Huisman
Pinar Yilmaz | Tugba Akinci D' Antonoli | Vera Cruz e Silva

AFFILIATION

European Society of Medical Imaging Informatics (EuSoMII) Education Committee



CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

<↑> HYPERLINK

info@eusomii.org

/ Chapter Outline

/ IT-architecture

- / Interoperability
- / Hospital Information System (HIS)
- / Electronic Health Record (EHR)
- / Radiology Information System (RIS)
- / Picture Archiving and Communication System (PACS)
- / Digital Imaging and Communications in Medicine (DICOM)
- / Health Level 7 (HL7)
- / Integrating the Healthcare Enterprise International (IHE)

/ Basic Workflow of Medical Imaging

- / Past and Present
- / Scheduled Workflow IHE profile

/ Radiology Reporting

- / Traditional Reporting
- / Structured Reporting
- / Traditional Reporting vs. Structured Reporting
- / The Radiology Report of the Future

/ Take-Home Messages

/ References

/ Test Your Knowledge

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of
Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ IT- architecture

/ IT-architecture

IT-architecture in radiology refers to the **underlying technological framework** that supports the nowadays fully digital workflow of a radiology department.

The core infrastructure of any modern radiology department is made up of **modalities** (e.g. computed tomography (CT) or x-ray), **computers, software**, the **connectivity or networking capability** between these devices and local servers or cloud servers.

Exchange between modalities, **PACS** (see key terms), scheduling, billing, dictation, and reporting systems is made possible through the adherence to internationally recognised standards.

Computer systems are quite **diverse** and are often **purpose-build**. For instance, file servers prioritize rapid storage access and data transfer, while PACS client display stations offer diagnostic quality image display.



CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Interoperability

Interoperability refers to the ability of different computer systems, software applications, and devices to **access, integrate, communicate, exchange, and use data in a coordinated manner**.

For example, in a hospital, you might have **various systems** like Electronic Health Records (EHR), Radiology Information System (RIS), Picture Archiving and Communication System (PACS), and Laboratory Information Systems (LIS). Interoperability ensures that these systems can **share patient information, diagnostic images, and test results** seamlessly without any hiccups or delays.

Good interoperability improves the **overall efficiency of healthcare delivery, reduces errors, and enhances patient care**.

The **Digital Imaging and Communications in Medicine (DICOM) standard** is a great example of a means to facilitate and improve interoperability.

Interoperability is only possible by the use of **standardized protocols** (called 'standards'), for example those endorsed by the Integration the **Healthcare Enterprise (IHE)**



Image created with Bing Image Creator

<!=> ATTENTION

Interoperability is about making sure all the tech tools can "talk" to each other, share information, and work together smoothly, regardless of the manufacturer or developer, avoiding a "Babylonian confusion".

CHAPTER OUTLINE:

IT-architecture

/ Interoperability

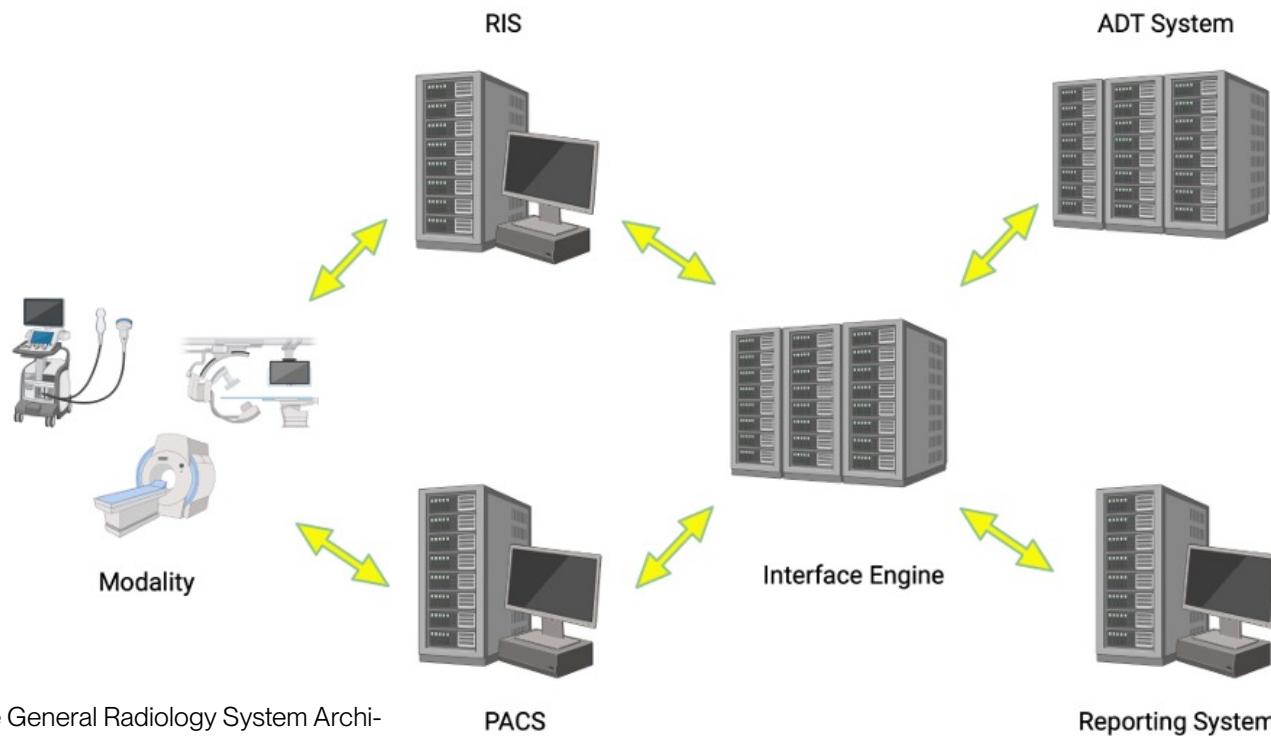
Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge



The General Radiology System Architecture is depicted with each arrow representing a need for interoperability. As mentioned before interoperability is pivotal for proper functioning and communication of different systems.

Image created with Biorender.com

CHAPTER OUTLINE:

- IT-architecture**
 - / Interoperability
 - Basic Workflow of Medical Imaging
 - Radiology Reporting
 - Take-Home Messages
- References
- Test Your Knowledge

/ Hospital Information System (HIS)

A HIS refers to a **comprehensive, administrative and operational** information system designed to facilitate all **operational tasks** in the hospital.

It enables an overview of everything that happens in the hospital from arrival and departure of a patient to financial aspects.

Key features of a HIS include:

- / Patient registration and management
- / Appointment scheduling and tracking
- / Inpatient and outpatient management
- / Billing and financial management
- / Inventory and asset management
- / Human resources management
- / Hospital performance analysis and reporting

1. Patient's personal information:
 - Full name: John Doe
 - Date of birth: 15 January 1980
 - Gender: Male
 - Address: 123 Elm Street, 98765 Anytown, Germany
 - Phone number: +49 555 1234567
 - Emergency contact: Jane Doe (spouse), +49 555 9876543
2. Insurance details:
 - Insurance provider: EuroHealthCare
 - Policy number: EHC123456789
 - Group number: G1234
 - Coverage details: Comprehensive plan, covers in-network and out-of-network providers
3. Visit-related information:
 - Date and time of visit: 1 June 2023, at 10:00
 - Reason for visit: Scheduled appointment for an annual physical and chest X-ray
 - Referring physician: Dr. Alice Johnson, Primary Care Physician
 - Department or clinic: Primary Care Clinic and Radiology Department
 - Attending physician or healthcare provider:
 - Primary Care Clinic: Dr. Mary Smith
 - Radiology Department: Dr. Peter Brown (for the chest X-ray)

CHAPTER OUTLINE:

- IT-architecture**
 - / HIS and EHR
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ Electronic Health Record (EHR)

EHR, also known as Electronic Medical Record (EMR), or Electronic Patient Record (EPR), is a **digital version of a patient's medical history**, maintained by healthcare providers over time.

It contains **key clinical data relevant to a patient's care**, such as demographics, medical history, medications, allergies, immunizations, lab results, radiology reports, surgery and pathology reports, and treatment plans. EHR gives **access to radiology reports for clinicians**, while it provides **clinical information to radiologists** for accurate image interpretation.

Although the EHR is **typically maintained by one healthcare provider**, EHRs are **designed to be shared across different healthcare settings**, allowing for efficient collaboration among healthcare professionals.

>|< **COMPARE**

HIS or EHR? HIS focuses on the administrative and logistical aspects of running a hospital, while EHR focuses on managing and sharing clinical information about patients.

Depending on the country, privacy regulations can be a big barrier to interhospital data sharing.

Patient's personal information:

- Full name: John Doe
- Date of birth: 15 January 1980
- Gender: Male
- Address: 123 Elm Street, 98765 Anytown, Germany
- Phone number: +49 555 1234567
- Emergency contact: Jane Doe (spouse), +49 555 9876543

Medical history:

- Chronic conditions: Hypertension
- Medications: Lisinopril 10mg daily
- Allergies: Penicillin
- Surgeries: Appendectomy (2005)

Clinical notes:

- Physical examination findings: Blood pressure 130/80 mmHg, heart rate 72 bpm, normal heart and lung sounds, no peripheral edema
- Lab results: CBC, CMP, and lipid panel within normal limits
- Chest X-ray results: Clear lung fields, no acute cardiopulmonary abnormalities

Assessment and plan:

- Annual physical: No concerning findings, continue monitoring blood pressure and medications
- Chest X-ray: Normal, no follow-up needed
- Next appointment: Annual physical exam in 1 year or as needed for any concerns

Example of mock data stored in a EHR generated with ChatGPT 4.0

CHAPTER OUTLINE:

IT-architecture

/ HIS and EHR

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Radiology Information System (RIS)

RIS is a specialized information system used to **manage patient data, radiology workflows, and administrative tasks in a Radiology department.**

It streamlines the radiology workflow by automating processes such as patient registration, appointment scheduling, examination ordering, image and report tracking, and billing. Integrating RIS with PACS into one software environment can further enhance the overall efficiency of the Radiology department.

The RIS is responsible for generating the **unique exam accession numbers** that are necessary for tracking studies in PACS.

The protocol that RIS uses for communicating with other systems is **HL7 (Health Level 7)**.

ATTENTION

RIS is like the control center for managing everything that goes on in a Radiology department.

Patient's personal information:

- Full name: John Doe
- Date of birth: 15 January 1980
- Gender: Male
- Address: 123 Elm Street, 98765 Anytown, Germany
- Phone number: +49 555 1234567
- Emergency contact: Jane Doe (spouse), +49 555 9876543

Radiology visit information:

- Accession number: RDX987654321
- Date and time of visit: 1 June 2023, at 11:30
- Referring physician: Dr. Alice Johnson, Primary Care Physician
- Radiology Department: Dr. Peter Brown (for the chest X-ray)
- Reason for exam: Annual physical examination, chest X-ray to screen for any abnormalities
- Exam type: Chest X-ray, PA and lateral views

Radiology exam details:

- X-ray machine used: Siemens Multix Fusion Max
- X-ray technician: Lisa Martin
- Radiation dose: 0.1 mSv

Radiology report:

- Radiologist: Dr. Peter Brown
- Date of interpretation: 1 June 2023
- Findings: Clear lung fields, no acute cardiopulmonary abnormalities, normal mediastinal contours, and bony thorax unremarkable
- Impression: No significant abnormality detected

CHAPTER OUTLINE:

- IT-architecture
- / RIS
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ Picture Archiving and Communication System (PACS)

PACS originated in radiology, and is the **core technological infrastructure that stores, distributes, manages and displays digital images**. Most PACS are installed on local servers with a few being cloud based. However, there is an ongoing shift to completely cloud-based PACS/RIS.

The functionality of PACS is enhanced when combined with other clinical application systems, including the hospital information system (HIS), electronic health records (EHR), radiology information system (RIS), image post-processing systems and dictation or voice

recognition systems for generating reports.



Image created with
Bing Image Creator

↔ ATTENTION

Think of PACS as a digital photo album for medical images.

The **core components** of a traditional PACS environment include:

- / Acquisition devices (modalities, post-processing workstations)
- / Network
- / Archive (short-term and long-term)
- / Database (demographics, exam description, associated reports etc)
- / Image viewers (web-based or 'diagnostic')
- / Interface engine/broker
- / Other (connected) clinical systems like RIS and HIS

A relatively recent development is that it can be used by any medical image producing department. This is called 'Enterprise PACS' if serving several departments, e.g., radiology, pathology, radiation oncology. The main difference between domains is the workstation connected to the PACS.

CHAPTER OUTLINE:

IT-architecture

/ PACS

Basic Workflow of
Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Digital Imaging and Communications in Medicine (DICOM)

DICOM is the **international standard** for the transmission, storage, and sharing of medical images and related information.

Systems that are compatible with the DICOM standard, are accompanied with the DICOM Conformance Statement. It ensures that different imaging equipment, PACS, and RIS from various manufacturers are **interoperable** and thus can **communicate with each other seamlessly**. It is widely used in Radiology and enables efficient image sharing and collaboration among healthcare professionals. DICOM files are also used in pathology and telemedicine.

The DICOM protocols specify how to retrieve and exchange images between PACS and an archive.

>< COMPARE

Standard vs. protocol: what's the difference?

A protocol defines a set of rules used by two or more parties to interact between themselves (=computer language).

A standard is a formalized protocol accepted by most of the parties that implement it.

<> REFERENCE

More on DICOM:
<https://www.dicomstandard.org/>

CHAPTER OUTLINE:

IT-architecture

/ DICOM, HL7, IHE

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Health Level (HL7) and FHIR

Health Level Seven International (HL7) is a **set of standards** used to exchange and share healthcare data between different healthcare systems, applications, and devices.

HL7 is a non-profit organization that develops these standards, with the primary goal of **simplifying the exchange of clinical information** across different healthcare providers and systems. The term "Health Level Seven" refers to the highest level (level seven = application layer) in the International Organization for

Example of HL7 (V2) for a new patient registration:

```
MSH|^~\&|ADT1|REG|EHR|EHR|202105011230||ADT^A04|123456|P|2.3
EVN|A04|202105011230|||
PID|1|12345|12345^^EHR^MR||DOE^JOHN^M||19700101|M|||123 MAIN
ST^ANYTOWN^NY12345||(555)555-5555|||||987654321
NK1|1|DOE^JANE^A|SPO||||||ORGANIZATION
PV1|1|I|ICU^01^02^EHR|||||||||||-
SUR|||||||||||||||202105010000
```

Example with mock data created with ChatGPT 4.0

Standardization's (ISO) seven-layer OSI (Open Systems Interconnection) communication model, which focuses on application-to-application communication.

One of the most widely used HL7 standards is the HL7 Version 2.x (V2) messaging standard. It is a flexible, text-based standard that defines the structure and format of messages to be exchanged between various healthcare IT systems.

Another significant, more modern (since early 2010) web-based, HL7 standard is the Fast **Healthcare Interoperability Resources (FHIR, pronounced "fire")** standard, meant to be easier to implement and more flexible. The shift from HL7 (V2), that has been the data interchange standard for more than 30 years, is already taking place.

<> REFERENCE

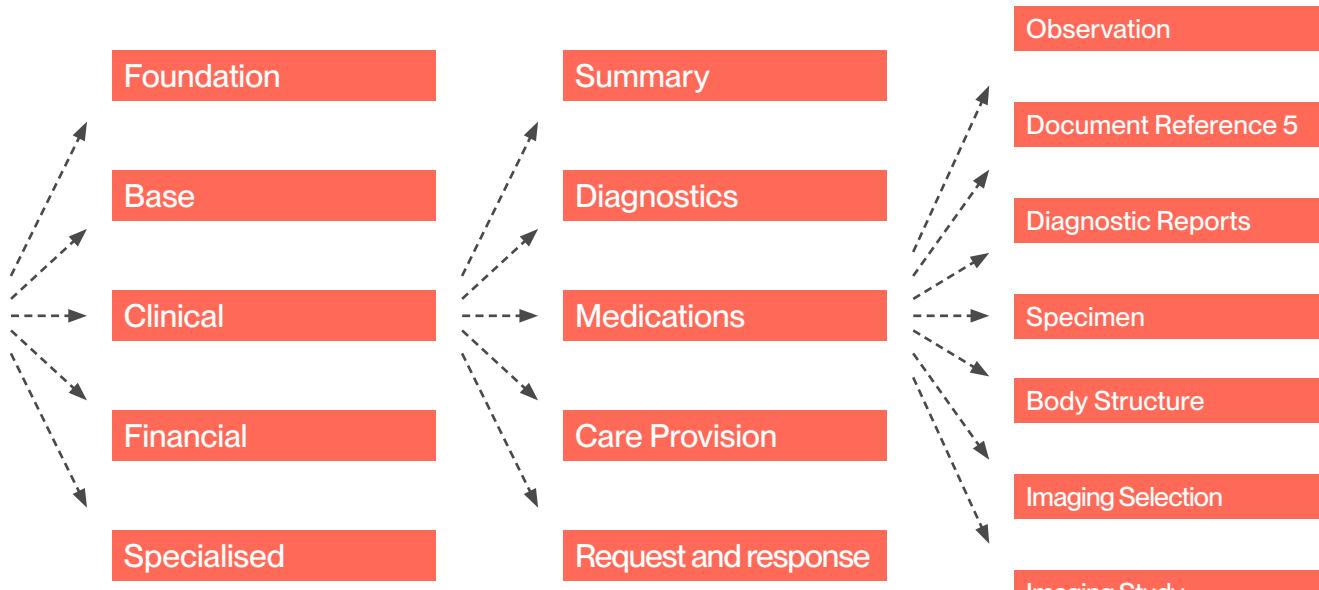
<https://www.hl7.org/>
https://en.wikipedia.org/wiki/OSI_model

CHAPTER OUTLINE:

- IT-architecture**
 - / DICOM, HL7, IHE
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ FHIR

In comparison to the previously broadly used HL7v2, FHIR breaks down the information for each patient into individual components known as resources (think of it as groups). There are 5 groups, currently consisted of 161 resources:



<∞> REFERENCE

For more details about the FHIR resources check <https://build.fhir.org/resourcelist.html>

CHAPTER OUTLINE:

- IT-architecture
 - / DICOM, HL7, IHE
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ FHIR and modular structure of data

The practicality of the resources is that **different systems need different data**. For instance Radiology images are not needed in EHR, information about the costs of hospital stay are not needed for PACS etc. Thus, the programme can retrieve and use only the information needed.

<=> FURTHER KNOWLEDGE **<=> REFERENCE**

<?> QUESTION

Click on the following link. Can you find how many mg Theophylline the patient will take after discharge and the reason why Ventolin inhaler is discontinued? Check first the XML/JSON tab and then the Narrative Content. The control+F function can help you navigate faster through the code.

[Narrative Content](#) [XML](#) [JSON](#) [TTL](#)

You might have noticed that information was structured in resources. You now realise that for example PACS can easily access the needed demographic details and skip the resources about medication of discharge.

CHAPTER OUTLINE:

- IT-architecture**
 - / DICOM, HL7, IHE
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ FHIR and interoperability

Interoperability in FHIR is ensured by the **use of standardized terminologies and ontologies** as explained later on this chapter.

Moreover, FHIR leverages **widely used and platform-independent web technologies** such as HTTP(S), JSON, and XML.

- / **HTTP(S):** Enables secure communication between systems over the web.
- / **JSON and XML:** Standard data formats that allow easy data exchange and integration between different applications.

By using these common technologies, **FHIR simplifies the process of integrating healthcare data into existing web-based systems and makes it easier for developers to create new applications** that interact with medical data seamlessly.



CHAPTER OUTLINE:

- IT-architecture**
 - / DICOM, HL7, IHE
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ Integrating the Healthcare Enterprise International (IHE)

Integrating the Healthcare Enterprise International (IHE) is an **initiative that aims to improve interoperability**. In simple terms, it is a group effort to make sure different healthcare systems can "talk" to each other and work together efficiently.

IHE brings together healthcare professionals, IT experts, and companies that create healthcare equipment and software. They work together to develop **guidelines called "Integration Profiles"**, in which roles, use-cases (applications) are identified and broken down into individual steps. Put simply, Integration Profiles are like **recipes that show how to combine different healthcare IT standards**, like HL7 and DICOM, to solve specific communication problems between systems.

By following Integration Profiles, hospitals and healthcare providers can make sure their systems work well together, which helps them provide better care for their patients.

In a nutshell, IHE is all about helping the healthcare industry and users **improve communication and collaboration between various IT systems** to provide more efficient and high-quality patient care.



CHAPTER OUTLINE:

IT-architecture

/ DICOM, HL7, IHE

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

CHAPTER OUTLINE:

IT-architecture

**Basic Workflow of
Medical Imaging**

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Basic Workflow of Medical Imaging

/ Past and Present

Before the introduction of PACS in the 1990s, X-rays were printed on films and interpreted on lightboxes, leading to an increased volume of films needed to be stored. All the X-rays were then stored in cabinets and the retrieval and hanging of the pictures was very time consuming.

Digital storage and viewing of radiological examinations changed the radiology workflow. However, the digitalisation of the exams affected not only the workload but also the workflow. From acquisition of images linked to specific patient data, interpreting exams and writing reports to archiving the exams and reports the workflow was strongly affected.

Did you ever wonder why personnel in radiology uses the term hanging protocol instead of display protocol?



Lightboxes for image interpretation. Courtesy, Prof. Karantanas, University Hospital of Heraklion, Crete, Greece

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

/ Past and Present

Radiology Reporting

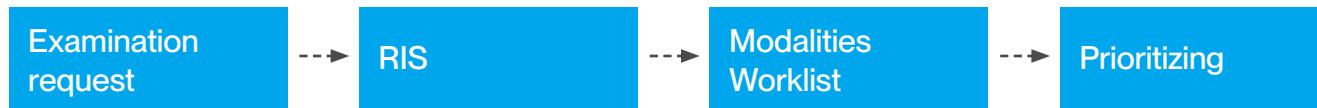
Take-Home Messages

References

Test Your Knowledge

A typical example of workflow in Radiology starts by a request sent by a clinician containing necessary information such as patient data, requested exam as well as clinical questions and comorbidities that might affect the exams i.e renal failure that limits the use of i.v contrast agent. Then, the request initiates a cascade of steps with the first one being generating and transmitting the order to RIS.

A DICOM modality worklist is created by RIS (or another IS) and the exam is scheduled in terms of time, modality and technique (i.e. the different phases on CT or the different sequences on MR). Usually, the radiologist would be the one to approve the referral on RIS and prioritize the exam based on the local or national guidelines.

**CHAPTER OUTLINE:**

IT-architecture

Basic Workflow of Medical Imaging

/ Past and Present

Radiology Reporting

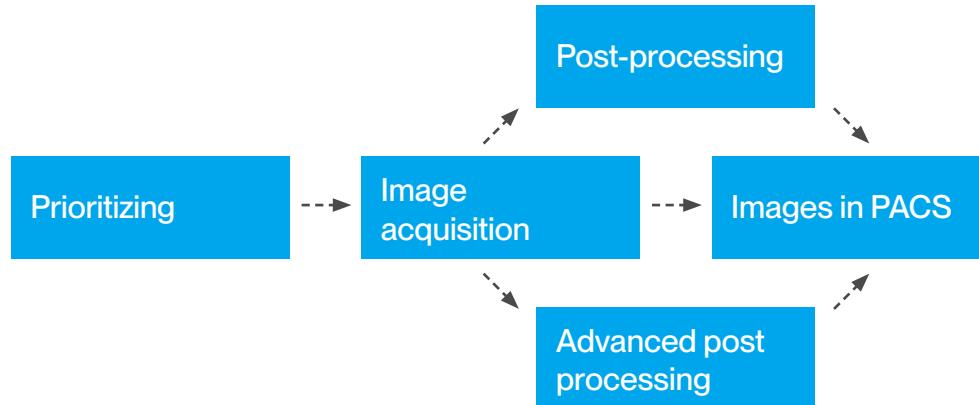
Take-Home Messages

References

Test Your Knowledge

The technicians acquire the images on modalities and send them to the PACS. Then, post-processing can be performed by technicians based on the local routines. Post-processing refers to

multiplanar reformatting of images, 3D reformatting, different window series: skeletal - lung windows etc. Advanced post-processing and artificial intelligence algorithms can also be initiated at this point.

**CHAPTER OUTLINE:**

IT-architecture

Basic Workflow of Medical Imaging

/ Past and Present

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

Patient data, imaging data and post-processing data are available on the radiologist's workstation which is a high-performance computer. With all the data available the radiologist can start reporting in the Reporting System often using a speech recognition programme.

In the end, the reports are sent from RIS to the Electronic Health Record (EHR) where they are available to the referring physician.

**CHAPTER OUTLINE:**

IT-architecture

Basic Workflow of Medical Imaging

/ Past and Present

Radiology Reporting

Take-Home Messages

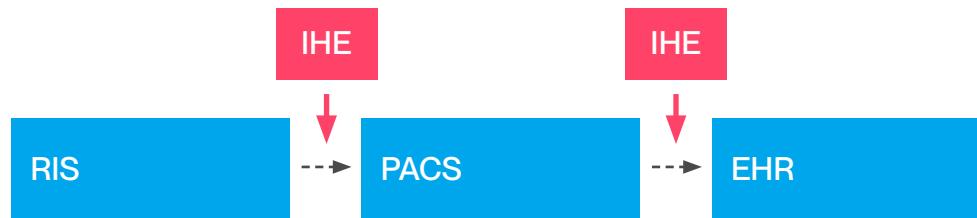
References

Test Your Knowledge

/ Scheduled Workflow IHE Profile

At first glance one can easily realise that multiple information systems are used in the radiological workflow. HL7-encoded messages are transmitted between the information systems and the final goal is to produce and interpret DICOM images and send these information to the referral doctors.

While all the information systems are well defined special interest has been shown to the **interface between these** independent systems and how these systems can be **interoperable**. That is the role of IHE - Scheduled workflow profile

**CHAPTER OUTLINE:**

IT-architecture

Basic Workflow of Medical Imaging

/ Scheduled Workflow IHE Profile

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

There are numerous IHE profiles that are addressed to Radiology. Those profiles are divided into groups. Among those groups there is the “workflow profiles” group which contains the Scheduled Workflow profile (SWF).

The SWF profile coordinates ordering, scheduling, imaging acquisition, storage and viewing of the radiological exams.

IHE profiles for radiology

Workflow profiles

Scheduled Workflow Profile

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

/ Scheduled Workflow IHE Profile

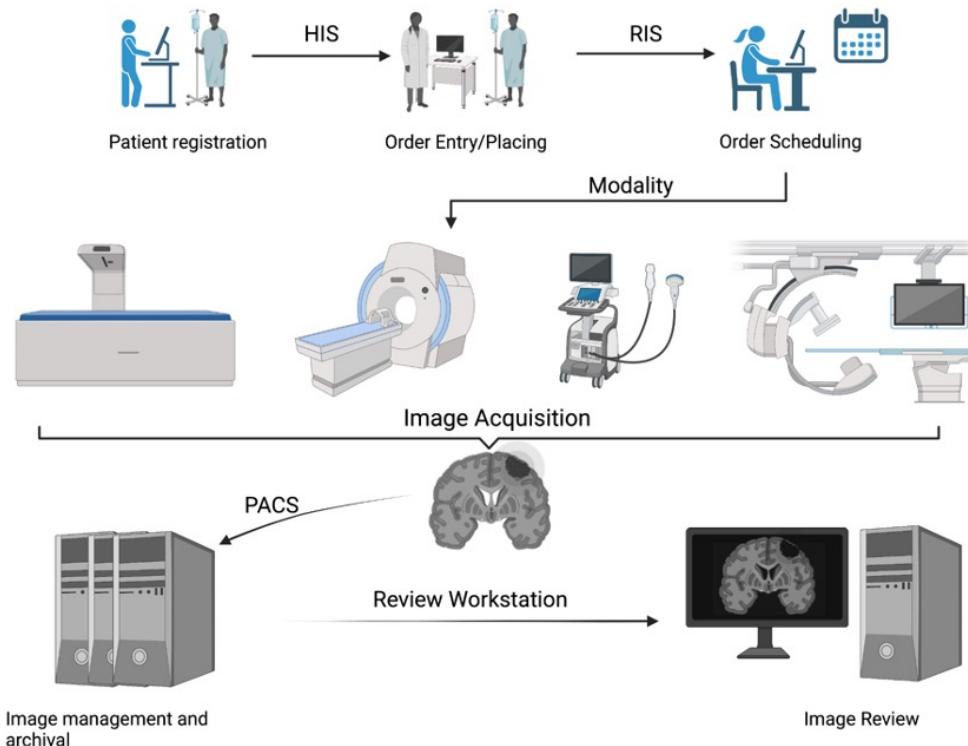
Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

Schematic representation of the SWF IHE profile which ensures data availability and consistency. Created with Biorender



<> REFERENCE

https://wiki.ihe.net/index.php/Scheduled_Workflow
<https://pubs.rsna.org/doi/epdf/10.1148/radiol.2292031199>

Created with BioRender.com

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

/ Scheduled Workflow IHE Profile

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

The benefits of SWF profile can be divided into 3 categories and some of them are:

- / Benefits that minimise errors and improve patient care by
 - / Eliminating mistakes in manual data entry as every piece of data is entered only once
 - / Preventing complications related to allergies or pregnancy status by making the information available to all systems involved in the workflow
- / Those that enhance efficiency by
 - / Saving time spent on manual data entry (data is entered only once).
 - / Ensuring accurate tracking of study identification
 - / Reducing the time wasted by staff on identifying and correcting errors across various systems such as HIS, RIS, PACS, and modality.
- / Benefits that reduce cost and deployment time by
 - / Eliminating the need for time-consuming and expensive custom interface specifications by utilizing the detailed specification provided by IHE technical framework, which is supported and tested by numerous vendors.
 - / Reducing the time and cost associated with interface compliance
 - / Reducing the need for maintaining multiple custom interfaces, resulting in savings in time and expenses, by utilizing a single interface (IHE) instead.

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging**
 - / Scheduled Workflow IHE Profile
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

Other examples of workflow IHE profiles that are under the radiology IHE profile umbrella are **Reporting Workflow profile** (focused on reporting tasks), **Post-Processing Workflow profile** (tracking post-acquisition tasks), Import Reconciliation Workflow profile (refers to import workflow from CDs, USBs, hardcopies -printed films- etc). It becomes clear that different workflow profiles ensure the proper functioning of the radiology workflow.



Did you know that IHE runs connectathons? Connectathons are “connectivity marathons” which last 5 days and in which testing of interoperability of health systems is performed!

IHE connectathon. Courtesy IHE-Europe

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

/ Scheduled Workflow IHE Profile

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting**
- Take-Home Messages
- References
- Test Your Knowledge

/ Radiology Reporting

/ Radiology Reporting

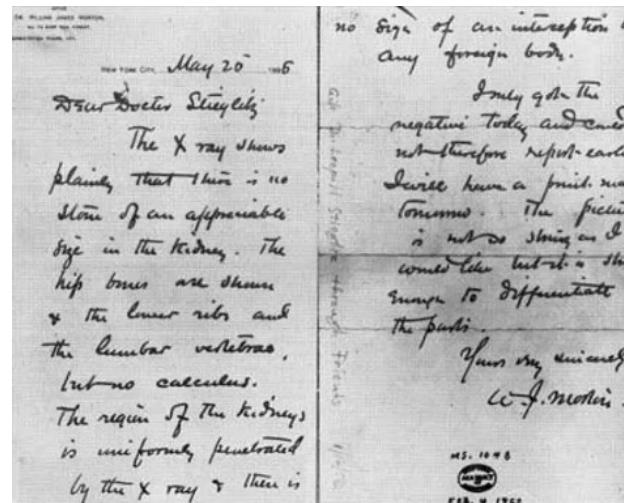
The primary work of a radiologist is to **interpret and communicate imaging findings** to referring physicians.

Essential to radiology reports are to produce a report which:

1. Enhances interpretation
2. Contains a lot of informative data
3. Is of high value and decisive for patient management

Nowadays, **speech recognition** is used to generate the reports instead of written or recorded findings.

Two approaches of reporting are **traditional** and **structured reporting**. The main product in both methods involves clear communication of information. However, there are differences in format, organization, level of standardization and automatic interpretability of the report.



<=> ATTENTION

The earliest radiology report was a written letter by Dr. William J. Morton of New York in 1896.

Today's reports still have the same formatting.

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Take-Home Messages

References

Test Your Knowledge

/ Traditional Reporting

Traditional reporting refers to the conventional approach of conveying information in a narrative form. And is also seen in newspaper articles, magazine features, or news broadcasts. Key characteristics of traditional reporting include:

- / **Narrative Format:** Traditional reporting typically follows a storytelling format, presenting information in a narrative structure with an introduction, body, and conclusion. It allows for a more descriptive and creative presentation of facts and events.
- / **Flexibility:** This form of reporting offers more flexibility in terms of writing style and content organization. The freedom to choose the order of information and emphasize certain aspects based on judgement and storytelling techniques can be considered in certain difficult cases.
- / **Subjectivity:** Sometimes this style can involve subjective elements, such as opinions, interpretations, or biases. While professionals strive for objectivity, these human factors can influence the reporting to some extent.

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting**
 - / Traditional Reporting
- Take-Home Messages
- References
- Test Your Knowledge

/ Structured Reporting

Structured reporting involves a standardized format for presenting information to improve clarity, consistency, and ability to extract data for analysis. Three attributes of structured reporting as described by CP. Langlotz in 2015 include:

Format

Structured reporting is based on templates or forms to organize and present information in a consistent format.

Organization

Standard ordering of information by dividing the report into sections, headings, and consistent organization of imaging observations within the text (for example, describing the liver first, followed by the gallbladder etc.).

Standard Terminology

Standardized language is used to report and interpret imaging findings with uniform terminology. This facilitates comparison, communication and data retrieval.

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of
Medical Imaging

Radiology Reporting
/ Structured Reporting

Take-Home Messages

References

Test Your Knowledge

<> REFERENCE

Langlotz CP. The radiology report: a guide to thoughtful communication for radiologists and other medical professionals. 1st ed. San Bernardino: CreateSpace Independent Publishing Platform; 2015.

The Radiological Society of North America, American Society of Radiology and European Society of Radiology have created ontologies, lexicons like RadLex (www.radlex.org) and RadElement.org which is a site offering a list of **Common Data Elements (CMEs)**.

Common Data Elements are all the possible **units of information** in a report. For instance, an aortic dissection can be acute, subacute, chronic, indeterminate or unknown and those are 5 **different values** that a CME can have.

Examples of standardized ontologies besides RadLex are Logical Observation Identifiers Names and Codes (**LOINC**) and Systematized Nomenclature of Medicine Clinical Terms (**SNOMED-CT**).

<> FURTHER KNOWLEDGE

Check the format of RadElement.org. Can you think of different applications?

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

/ Structured Reporting

Take-Home Messages

References

Test Your Knowledge

<> REFERENCE

Rubin DL, Kahn CE Jr. Common Data Elements in Radiology. *Radiology*. 2017 Jun;283(3):837-844. doi: 10.1148/radiol.2016161553. Epub 2016 Nov 10. PMID: 27831831.

Other well-known standardized terminologies are the Fleischner criteria for pulmonary nodules and reporting and data systems for breast imaging (BI-RADS), coronary artery disease (CAD-RADS), liver imaging (LI-RADS) and prostate imaging (PI-RADS). The consistent terminology allows categorizing imaging findings into probabilities and if necessary further interventions.

Different Reporting and Data Systems in different languages are available [here](#)

CT/MRI Diagnostic Table

Arterial phase hyperenhancement (APHE)		No APHE		Nonrim APHE		
Observation size (mm)		< 20	≥ 20	< 10	10-19	≥ 20
Count additional major features:	None	LR-3	LR-3	LR-3	LR-3	LR-4
	One	LR-3	LR-4	LR-4	LR-4	LR-5
	≥ Two	LR-4	LR-4	LR-4	LR-5	LR-5

LR-4
LR-5

Observations in this cell are categorized based on one additional major feature:
 • LR-4 – if enhancing "capsule"
 • LR-5 – if nonperipheral "washout" OR threshold growth

LIRADS - Diagnostic Table for HCC suspicious lesions. American College of Radiology Committee on LI-RADS®. CT/MRI LI-RADS® v2018 CORE. Available at <https://edge.sitecorecloud.io/americancoldf5f-acrorgf92a-productioncb02-3650/media/ACR/Files/LI-RADS/LI-RADS/LI-RADS-CT-MRI-2018-Core.pdf>

! ATTENTION

BI-RADS was the first in-practice reporting system to develop a lexicon to standardize and improve uniformity in mammography reporting.

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

Structured Reporting

Take-Home Messages

References

Test Your Knowledge

/ Structured Reporting Pros and Cons

PROS:

- + Standardises resident training and improves evaluation of reporting skills.
- + Improves completeness and reduce misses by using checklists, boosting detection and diagnostic accuracy.
- + Supports clinical decision-making and staging, linking radiology more closely to patient care.
- + Minimises typos by replacing error-prone dictation with proofed templates.
- + Enables quick data extraction and support research and clinical decisions.

CONS:

- Radiologists focus on filling the templates instead of searching for findings leading to increase of misses.
- Errors can arise when auto-filled phrases aren't updated for individual cases, like misreporting absent organs as normal.
- Structured reporting can be limiting in complex cases, where rigid formats hinder comprehensive, multiple-system descriptions.
- Structured reports may reduce productivity in busy settings due to increased time and workflow steps.

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting**
 - / Structured Reporting
 - Take-Home Messages
 - References
 - Test Your Knowledge

/ Traditional vs. Structured Reporting

Traditional Reporting

PATIENT NAME: JOHN SMITH
 PATIENT ID: 0123456789
 DATE OF EXAM: 01/01/2023

CT ABDOMEN AND PELVIS WITH CONTRAST

CLINICAL HISTORY: Abdominal distention and constipation

TECHNIQUE: Axial and coronal CT images of the abdomen and pelvis were obtained following the administration of intravenous contrast material.

FINDINGS: There is diffuse wall thickening of the sigmoid colon with associated pericolic fat stranding, consistent with sigmoid diverticulitis. No abscess, perforation, or extraluminal air is identified. The remainder of the colon is unremarkable, with no evidence of obstruction. The liver is normal in size and morphology, and no intrahepatic or extrahepatic biliary duct dilation is noted. The gallbladder and pancreas are unremarkable. The spleen and adrenal glands appear normal. Both kidneys demonstrate no evidence of hydronephrosis, and the ureters are unremarkable. The small bowel loops appear normal, without obstruction, wall thickening, or dilatation. The uterus is normal in size and contour, with both ovaries appearing normal and no adnexal masses or free fluid noted. The urinary bladder is partially distended but otherwise unremarkable.

IMPRESSION: Diffuse sigmoid diverticulitis with associated pericolic fat stranding, without evidence of abscess, perforation, or extraluminal air.

REFERENCE

Santiago I, Figueiredo N, Parés O, Matos C. MRI of rectal cancer-relevant anatomy and staging key points. Insights Imaging. 2020 Sep 3;11(1):100. doi: 10.1186/s13244-020-00890-7. PMID: 32880782; PMCID: PMC7471246.

Structured Reporting

Pelvic MRI for low rectal cancer staging	
Clinical information	
Technique	High resolution T2-WI in sagittal, oblique axial and oblique coronal planes, and oblique axial DWI were acquired after a small enema (...) and spasmodic agent administration (...).
Results	
The tumour is infiltrative and not partially mucinous . Clearly	
It's caudal edge is located ...mm above at the level of the anal verge and ...mm below the anorectal transition	
It is ...mm in length and its cranial edge is located at the level of the anterior peritoneal reflection ...mm below	
It extends from ... o'clock and its deepest edge is located between ... and ... o'clock , where it	
invades part of the anal musculosa . invades the whole stomach . invades part of the muscularis propria/interna sphincter . invades the whole muscularis propria/interna sphincter . invades the external sphincter (levator). invades the external sphincter/levator , into the left/right/both ischioanal space(s) . invades the prostate/uterus (clitoris/penis/buttocks/vagina).	
The peritumoural area shows no signal intensity changes not adjacent vessels . no signal intensity changes adjacent to normal-calibre vessel(s) . intermediate signal within vessel(s) with slight expansion . vessel(s) with irregular contour and clear tumoural signal .	
There are no suspicious mesorectal lymph nodes , none of which reaching the CRM . none of which invading the CRM at and none of which being superior hemorrhoidal/mesenteric . and none of which being superior hemorrhoidal/mesenteric .	
In the pelvic sidewalls (PSW), we find one suspicious lymph node at no suspicious lymph nodes at	
There are no extranodal tumour deposits at There are no extranodal tumour deposits at	
We find no relevant additional pelvic findings. There are the following additional relevant pelvic findings: (to include anatomic variants such as middle rectal veins/arteries and their entrance in the mesorectum)	
Conclusion	
Tumour between and o'clock , staged as mrLR.... mrT.... mrEMVI.... mrN.... (PSW....) ... (include relevant considerations such as extension of deepest edge, tumour implants in addition to N+, discontinuous mrEMVI outside the pelvis, high suspicious lymph nodes, metastases, etc....	

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

/ Traditional vs. Structured Reporting

Take-Home Messages

References

Test Your Knowledge

/ The Radiology Report of the Future

More research on Large Language Models and Structured Reporting is needed. The focus should be turned towards human VS LLM generated structured reports, overcoming regulatory frameworks and use of greater variety of LLM.¹

However, LLMs have already been proved valuable in summarising medical documentation.²

In the future, the radiology report will include standard formatting, terminology and structured data.

Natural Language Processing and Large Language Models will generate structured reports out of the natural language dictated by the radiologist. In specific, large language models will help to process, understand, and produce language that is close to human language as output.

AI applications will provide annotations of findings linked to the reports and structured reports of a broader spectrum of cases than today.

<> REFERENCE

1. Busch, F., Hoffmann, L., dos Santos, D.P. et al. Large language models for structured reporting in radiology: past, present, and future. *Eur Radiol* (2024). <https://doi.org/10.1007/s00330-024-11107-6>
2. Van Veen D, et al. Adapted large language models can outperform medical experts in clinical text summarization. *Nat Med*. 2024 Apr;30(4):1134-1142. doi: 10.1038/s41591-024-02855-5.

CHAPTER OUTLINE:

IT-architecture

Basic Workflow of Medical Imaging

Radiology Reporting

/ The Radiology Report of the Future

Take-Home Messages

References

Test Your Knowledge

/ Take-Home Messages

- / Radiology departments are fully digital nowadays and have their own systems to facilitate digital workflows, i.e. RIS and PACS
- / Interoperability refers to compatibility of computers systems and software, to exchange healthcare data seamlessly and safely.
- / The Scheduled Workflow IHE profile ensures that there is interoperability between the different information systems among the various steps.
- / Reporting is the primary work product of radiologists. In addition to traditional reporting, structured reporting can be considered to promote greater standardization within Radiology, including standard lexicons to enhance common terminologies and improve communication, workflow and patient care.



CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages**
- References
- Test Your Knowledge

/ References

Books:

- / The radiology report: a guide to thoughtful communication for radiologists and other medical professionals. 1st ed. San Bernardino: CreateSpace Independent Publishing Platform; 2015. Langlotz CP.
- / Artificial Intelligence in Medical Imaging, Opportunities, Applications and Risks, by Erik R. Ranschaert et al. 2019.
- / Practical Imaging Informatics, Foundations and Applications for Medical Imaging by Barton F. Branstetter et.al.
- / Basic Knowledge of Medical Imaging Informatics Undergraduate Level and Level I, by Peter M. A. van Ooijen et. al.
- / Structured Reporting in Radiology; 2022. Mansoor Fatehi et al.

Papers:

- / Bhargavan M, Sunshine JH. Workload of radiologists in the United States in 2002-2003 and trends since 1991-1992. Radiology. 2005 Sep;236(3):920-31. PMID: 16014442.
- / Moore SM. Using the IHE scheduled workflow integration profile to drive modality efficiency. Radiographics. 2003 Mar-Apr;23(2):523-9. PMID: 12640165.
- / Nobel et al. Redefining the structure of structured reporting in radiology. Insights into Imaging, volume 11, issue 1. PMID: 32020396.
- / Lawrence et al. Improving communication of diagnostic radiology findings through structured reporting. Radiology. 2011 Jul;260(1):174-81. PMID: 21518775.

Websites:

- / <https://www.ihe.net/>
- / https://wiki.ihe.net/index.php/Main_Page
- / https://miro.medium.com/v2/resize:fit:828/format:webp/1*S51TBXTIkuC2AjtqmPtsAg.png

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

/ Test Your Knowledge



<=?> QUESTION

1

The primary protocol for transmitting medical images from modalities to PACS is:

- HL7
- MDR
- DICOM
- IHE

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge



<=?> ANSWER

1

The primary protocol for transmitting medical images from modalities to PACS is:

- HL7
- MDR
- DICOM
- IHE

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge



<?> QUESTION

2

IHE stands for:

- International Healthcare Enterprise
- Integrating the Healthcare Enterprise
- International Healthcare Embodiment
- Integrating HL7 Effort

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge



<?> ANSWER

2

IHE stands for:

- International Healthcare Enterprise
- Integrating the Healthcare Enterprise
- International Healthcare Embodiment
- Integrating HL7 Effort

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

<=?> QUESTION

3

Which of the following steps is not part of the radiology workflow?

- An exam request is made by the clinician
- A modality worklist is created in RIS
- Images are acquired and sent to PACS
- Interesting exams are saved in separate folders for educational purposes
- Reporting of images by the radiologist

Medical
Imaging
Informatics

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

<=?> ANSWER

3

Which of the following steps is not part of the radiology workflow?

- An exam request is made by the clinician
- A modality worklist is created in RIS
- Images are acquired and sent to PACS
- Interesting exams are saved in separate folders for educational purposes
- Reporting of images by the radiologist

Medical Imaging
Informatics

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

<=?> QUESTION

4

Which of the following statements regarding structured reporting is correct:

- The Radiological Society of North America, American Society of Radiology and European Society of Radiology are cooperating on radreport.org and make templates available on a pay-per-use basis
- Structured reports allow for more flexibility than conventional free-text reporting
- Structured Reporting complicates radiology training
- Data-use from structured reports is limited on research
- Structured reporting aims to improve completeness and clarity of reports

Medical Imaging
Informatics

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

<=?> ANSWER

4

Which of the following statements regarding structured reporting is correct:

- The Radiological Society of North America, American Society of Radiology and European Society of Radiology are cooperating on radreport.org and make templates available on a pay-per-use basis
- Structured reports allow for more flexibility than conventional free-text reporting
- Structured Reporting complicates radiology training
- Data-use from structured reports is limited on research
- Structured reporting aims to improve completeness and clarity of reports

Medical Imaging
Informatics

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge

<?> QUESTION

5 Which of the following statements regarding terminologies and ontologies is NOT correct

- The Fleischner Society's Glossary for Thoracic Imaging encourages the use of various synonyms for "consolidation"
- Terminologies provide terms with defined meanings
- Ontologies provide terms with attributes and relations between them
- RadLex includes translations of English terms
- Logical Observation Identifiers Names and Codes (LOINC) specifies attributes like measurement scale and method

Medical Imaging
Informatics

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

/ Test Your Knowledge



<?> ANSWER

5 Which of the following statements regarding terminologies and ontologies is NOT correct

- The Fleischner Society's Glossary for Thoracic Imaging encourages the use of various synonyms for "consolidation"
- Terminologies provide terms with defined meanings
- Ontologies provide terms with attributes and relations between them
- RadLex includes translations of English terms
- Logical Observation Identifiers Names and Codes (LOINC) specifies attributes like measurement scale and method

CHAPTER OUTLINE:

- IT-architecture
- Basic Workflow of Medical Imaging
- Radiology Reporting
- Take-Home Messages
- References
- Test Your Knowledge**

