



# MEDICAL INFORMATICS STANDARDS

Prof. Yasser Mostafa Kadah – [www.k-space.org](http://www.k-space.org)

# DICOM

- Digital Imaging and Communications in Medicine (DICOM) is internationally accepted standard used for storing, exchanging, and transmitting medical image data
  - ▣ Features include image storage, retrieval, and display (today on monitors, previously via printing)
  - ▣ By agreeing and unifying on common standard, 'mixed-vendor' environment is possible
- In the early 1980s, as each manufacturer utilized proprietary encoding for images it became apparent that it was difficult for medical imaging to be viewed or stored outside of the boundaries of original acquisition modality
  - ▣ As a result, some hospitals were forced into purchasing all equipment from single manufacturer
- Recognizing need for greater co-ordination between different vendors and systems in new area of imaging informatics, groups began to debate possible solutions

# DICOM Standard

- In 1985, initial DICOM specification was first published jointly by National Electrical Manufacturers Association (NEMA) and American College of Radiology (ACR), with aim of allowing interoperability
  - ▣ Today, DICOM v3 remains in use and is now backed up by ISO 12052:2006 standard
  - ▣ Most recent DICOM standard is free and easily accessible on internet via NEMA website
- Current version of DICOM in use from 1993 onwards remains DICOM v3, which is still being developed, receiving regular updates but retaining the same version number
  - ▣ This is because all current updates are forwards and backwards compatible within the version, allowing for wide ranging compatibility between old and new equipment, even when recent technologies had not been foreseen originally such as Bluetooth connected DDR imaging plates
- Consequence of this interoperability is that estimated trillion medical images can be viewed and transferred with DICOM today, unlike other formats, which have peaked and waned over the same timeframe
  - ▣ Older equipment, such as legacy NM scanners, can happily co-exist on network with cutting-edge volume reconstruction or image analysis systems

# Function of DICOM

- DICOM as standard contains number of parts, with 18 (20 total, with two retired) as of 2017 that document and define standard way for data to be formatted, communicated, and presented by medical imaging systems during the creation, management, and exchange of those images
  - ▣ By creating common standard this allows imaging acquired on one manufacturer's device to be viewed on another compatible device much more widely, and is basis for how we are able to 'mix-and-match' different pieces of equipment within our departments
- DICOM standard overall defines:
  - ▣ Set of protocols (rules) for manufacturers to use
  - ▣ Syntax (arrangement) and semantics (meaning) of commands and data models (relationships)
  - ▣ Guidance on standardized formatting of data
  - ▣ Communication methods

# Common DICOM Terminology

- ❑ Modality: discrete type of imaging specialty such as CT, MR, CR, and US
- ❑ Application Entity Title (AET): 'names' of services or applications communicating within the network, typically used to identify individual pieces of image acquisition equipment
- ❑ Modality Worklist: service that provides collated feed of demographic and exam data to image acquisition equipment
- ❑ Query/Retrieve (Q/R): provides method to search (query) for particular attributes – normally a patient name, patient ID, or date of birth, etc., then to download (retrieve) matching examination data and images
- ❑ Association: connection or conversation between two programs
- ❑ Service-object pair (SOP) class: equivalent to 'topic' of conversation and is framed in context with actor ('thing' doing action) plus action required

# Common DICOM Terminology

- Service Class User (SCU) and Service Class Provider (SCP): two 'ends' of single connection at any one time – SCU is end initiating the contact, and SCP receiver or responder
- Composite and Normalised Operations
  - ▣ Composite operations (beginning with C-) are found as part of wider sets of instructions (common in PACS)
  - ▣ Normalized operations (beginning with N-) contain enough information to be free-standing as single instruction (rare)

DICOM term	Simplification
Application entity	Person
Association	Conversation
SOP class	Topic of conversation
SOP instance	Piece of information
Transfer syntax	Language
Service	Form of conversation (lecture, question and answer, reference sheet, etc.)
Off-line media	Printed book
AET	Person's name

# Basic DICOM File Movement Operations

- C-Store: send data for storage
  - As safety check, service known as storage commitment (SCM) can check that there is sufficient space prior to operation beginning, and at end that data have actually been stored before sending program discards data
    - Avoids equivalent of common issue found on standard operating systems where file copies for several minutes, before an 'out of memory' message is displayed
- C-Find: search for something and return results
- C-Move: copy a composite object in a new, following, association (that composite object is usually a DICOM image, but can be other rarer items)
- C-Get: also copies a composite object, but without starting a new association to do so
- C-Echo: similar to 'ping', checks low-level technical operation of connection and destination application

# Basic DICOM File Movement Operations

- Simplified basic process for establishing connections in DICOM consists of:
  - ▣ SCU (entity wanting something done) communicates with the SCP (entity that can likely do this), firstly negotiating technical protocol (mutually as fast as possible, but understandable language) leading to association (a conversation) being created
  - ▣ Through this association, requests are made and data are passed (using the composite operations above, or perhaps the normalized operations, as so needed)
  - ▣ Association is then closed



# DICOM Conformance Statement

- Important but extremely lengthy documents issued for each piece of equipment, such as a PACS, CR console, CT scanner, which detail in depth particular machine's specific compliance and implementation of the DICOM standard
- Although overall DICOM version has remained unchanged for years at version 3, additional functionality and methods have been added
- Reading the conformance statement of any new incoming piece of imaging equipment is critically important to determine any compatibility or workflow issues that may arise
- This review should be carried out well in advance of purchasing decision being made by those in charge of managing PACS in conjunction with department lead wishing to purchase or add new equipment

# Modality Performed Procedure Step (MPPS)

- Useful DICOM service, but not widely adopted within radiology community at present
- Allows for feedback to be sent from image acquisition station such that individual parts of diagnostic examinations can be sent separately, and status of these updated, also separately
  - ▣ For example, 'progress' update can be made on multi-body-part examinations with earlier images then being made available for review more quickly than entire examination; or staged dose information provided
- Partially provides similar functionality to historic requests for 'wet film' images
  - ▣ Clinicians requiring to see chemically-developed radiographs as soon as they were removed from the development process

# Composite Instances

- Meaning: ‘a part of more than one’
- By far most common composite instance is the DICOM image
- Presentation states: record of adjustments or manipulations made to diagnostic image, such that original image is not affected, and presentation state (changes) can be toggled at will in entirety
- Radiotherapy objects: similar to DICOM images produced as output to diagnostic encounters, but without pixel data (images), instead containing radiotherapy dose and planning information, etc.
- Structured reports: a ‘framework’ for issuing reports in reproducible manner (similar to each report being from a template)

# DICOM File

- Formally known as ‘DICOM data objects’ that consists of number of attributes (components)
  - ▣ Preamble (identifying file type and components)
  - ▣ Block of data (commonly known as DICOM headers, comprising patient demographics, technical information about image, study, its acquisition parameters, and acquisition device together with many other listed attributes)
  - ▣ Image data (single attribute that holds data required to recreate image pixels or voxels)

# DICOM Header

- Each image generated by medical equipment has, stored within, chunk of information about technical aspects of image, patient, and transfer methods at its start, followed by actual image data
- DICOM tag would read: **0008 0020 | 8 | study\_date | DA | 1 | “20130415”**
  - ▣ Two blocks of hexadecimal characters at the start of each row are Group and Element number – these reference parts of the standard and help equipment know what information is being presented
  - ▣ Length advises the maximum size of value
  - ▣ Description aids human interpretation by providing short explanation of row
  - ▣ Value Representation (VR) provides type of value system should expect to find (e.g., DT = Date and Time; UI = Unique Identifier; TM = time) from list contained within DICOM standard
  - ▣ Value Multiplicity (VM) indicates how many values are provided
  - ▣ Actual value is given at the end of row

Grp	Elmt	Length	Description	VR	VM	Value
0008	0005	10	specific_character_set	CS	1-n	"ISO_IR 100"
0008	0008	34	image_type	CS	1-n	"ORIGINAL\PRIMARY\AXIAL\CT_SOM5 SEQ"
0008	0016	26	sop_class_uid	UI	1	"1.2.840.10008.5.1.4.1.1.2"
0008	0018	56	sop_instance_uid	UI	1	"1.3.12.2.1107.5.1.4.54168.30000013041507523079600001239"
0008	0020	8	study_date	DA	1	"20130415"
0008	0021	8	series_date	DA	1	"20130415"
0008	0022	8	acquisition_date	DA	1	"20130415"
0008	0023	8	image_date	DA	1	"20130415"
0008	0030	14	study_time	TM	1	"113931.812000"
0008	0031	14	series_time	TM	1	"113931.812000"
0008	0032	14	acquisition_time	TM	1	"114006.015408"
0008	0033	14	image_time	TM	1	"114006.015408"
0008	0050	12	accession_number	SH	1	"100000794862"
0008	0060	2	modality	CS	1	"CT"
0008	0070	8	manufacturer	LO	1	"SIEMENS"
0008	0080	24	institution_name	LO	1	"ROYAL BROMPTON HOSPITAL"

# Unique Identifiers (UIDs)

- Several UIDs generated within each modality and included within produced images
  - ▣ Information about generating devices, patient, individual encounter, and files making up study
  - ▣ Each image within study contains number of different UIDs to link it to remainder of series, exam, and overall patient encounter (Hierarchy being: Patient > Study > Series > Image)
  - ▣ Globally unique from various issuing registries, which seek to avoid duplication by assigning batches to manufacturers and individuals or sites as required
  - ▣ UIDs generated for DICOM services all begin with the leading digits 1.2.840.10008[...] allowing for their easy recognition among wider network traffic

A Section of DICOM header  
(each row gives one DICOM tag)

UIDs

Grp	Elmt	Length	Description	VR	VM	Value
0008	0005	10	specific_character_set	CS	1-n	"ISO_IR 100"
0008	0008	34	image_type	CS	1-n	"ORIGINAL\PRIMARY\AXIAL\CT_SOM5 SEQ"
0008	0016	26	sop_class_uid	UI	1	"1.2.840.10008.5.1.4.1.1.2"
0008	0018	56	sop_instance_uid	UI	1	"1.3.12.2.1107.5.1.4.54168.30000013041507523079600001239"
0008	0020	8	study_date	DA	1	"20130415"
0008	0021	8	series_date	DA	1	"20130415"
0008	0022	8	acquisition_date	DA	1	"20130415"
0008	0023	8	image_date	DA	1	"20130415"
0008	0030	14	study_time	TM	1	"113931.812000"
0008	0031	14	series_time	TM	1	"113931.812000"
0008	0032	14	acquisition_time	TM	1	"114006.015408"
0008	0033	14	image_time	TM	1	"114006.015408"
0008	0050	12	accession_number	SH	1	"100000794862"
0008	0060	2	modality	CS	1	"CT"
0008	0070	8	manufacturer	LO	1	"SIEMENS"
0008	0080	24	institution_name	LO	1	"ROYAL BROMPTON HOSPITAL"

# Public Tags versus Private Tags

## Public Tags

- Public tags are 'common' tags that were internationally standardized by committee and likely to be found in all files
- These range from being common in every exam (patient name, date of birth, address, accession number, etc.), to only found in certain examinations (e.g. pitch, scan width, slice thickness in CT)
- Public tags have even group numbers (the first block of numbers on each row, such as [0008], [0010]).

## Private Tags

- Differentiated from public tags by their group numbers being odd numbers
- Contain pieces of image information that are either unique to equipment through which image was acquired, or are extra pieces of data provided beyond that available in public tags to allow for more specialty use
- Some uses of private tags may create vendor lock-in

0008	1030	12		study_description		LO		1		"12 Lead ECG"
0008	103e	20		series_description		LO		1		"HRCT_Expiration 1/10"
0008	1040	8		institutional_department_name		LO		1		"DEFAULT"
0008	1090	12		manufacturer_model_name		LO		1		"Sensation 64"
0010	0010	26		patient_name		PN		1		"SMITH^JONATHAN^^"
0010	0020	6		patient_id		LO		1		"123456"
0010	0030	8		patient_birth_date		DA		1		"19010101"
0010	0040	2		patient_sex		CS		1		"M"
0010	1010	4		patient_age		AS		1		"120Y"
0010	1030	4		patient_weight		DS		1		"52.8"

0011	1036	4		Unknown element		DS		?		"656"
0011	1037	18		Unknown element		DS		?		"-5.0\ -3.0\2.0\4.0"
0011	1042	16		Unknown element		LO		?		"antero-posterior"
0011	1044	16		Unknown element		CS		?		"DIGITALCASSETTE"
0011	1046	52		Unknown element		LO		?		"Chest\antero-posterior\Standard\MEDIUM ADULT\Custom1"
0011	1047	10		Unknown element		DS		?		"798.940247"
0011	1059	6		Unknown element		CS		?		"NORMAL"
0011	1064	12		Unknown element		CS		?		"URP_DETECTOR"
0011	1066	2		Unknown element		CS		?		"No"
0011	1067	4		Unknown element		CS		?		"None"
0011	1068	16		Unknown element		CS		?		"40:f4:a0:0:bc:b4"
0011	1069	10		Unknown element		CS		?		"-1.000000"
0011	106b	32768		Unknown element		US		?		"0x0000 0 ..."
0011	106d	18		Unknown element		DS		?		"217.30811552373711"
0011	1076	4		Unknown element		CS		?		"L\F"
0011	107d	2		Unknown element		CS		?		"NO"
0011	107e	2		Unknown element		DS		?		"0"
0011	1080	2		Unknown element		DS		?		"2"
0011	1081	2		Unknown element		LO		?		"AP"
0011	1082	18		Unknown element		CS		?		"GRID_FREQ_70_LP_CM"

# Photometric Interpretation

- Not all digital images are captured solely in greyscale
- Even when images are in greyscale, there is question as to which ‘way-around’ greyscale is applied in particular image
  - ▣ Example: in greyscale range of 0–255, is 0 the whitest pixel value with 255 being pure black or vice versa
  - ▣ During 2013, problems with incorrect photometric interpretation values were found, with legacy CR equipment images being displayed inverted when transmitted through data sharing services until update patch for original equipment was applied
- Photometric interpretation values are typically: Monochrome 2 (lowest pixel value is displayed black), Monochrome 1 (lowest pixel value is displayed white) or RGB (color)
  - ▣ Photometric interpretation DICOM tag is included in every image to ensure correct display

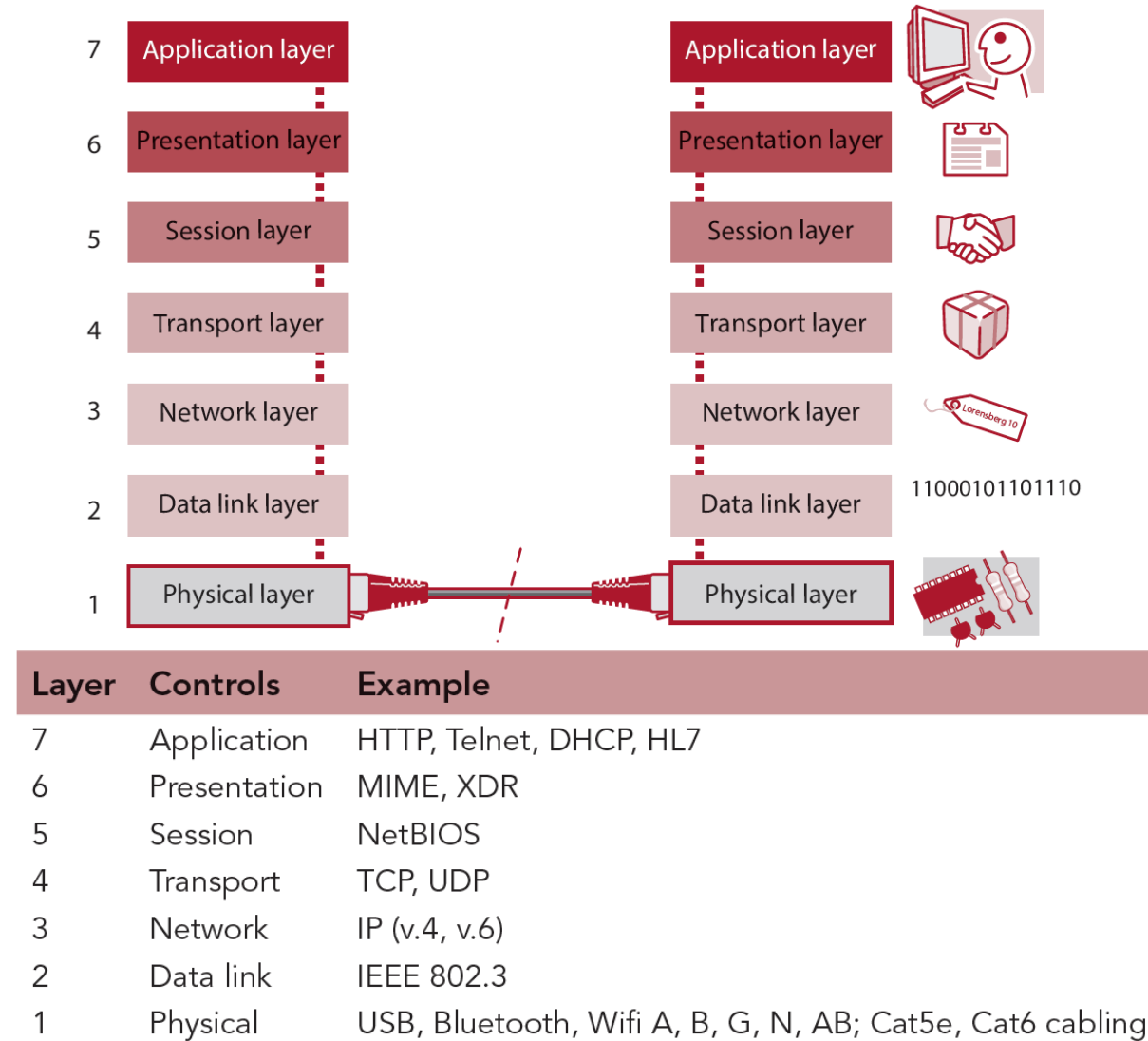


# Viewing DICOM Images Outside of PACS

- To view DICOM images away from original PACS viewer, dedicated program can be used to open files (e.g., Osirix or DICOMworks)
- It must be remembered that DICOM files contain patient demographics and episode details embedded within their header information
  - ▣ Thorough deidentification of teaching cases is very important to preserve confidentiality, particularly when working with images containing large number of private tags that may contain 'hidden' duplicate demographics not removed by the automated anonymization techniques
  - ▣ In daily practice, images viewed away from PACS environment are typically presented on what is known as 'offline media' (CD/DVD containing DICOM files, viewing application, and possibly other files)
    - Need to have structure table formed according to DICOM standard, commonly in form of DICOMDIR file in root directory (first folder of media) that has index of images, containing hierarchical structure of examination (Patient > Study > Series > Image) and setting out relation between each of images on disk to be displayed correctly
    - Without this file, some current PACS may not be able to import the studies as hierarchy may not be automatically recoverable without manual intervention

# Health Level Seven (HL7)

- Standard born out of need for connectivity and integration to enable exchange of textual healthcare information to benefit of patients
  - ▣ Originally developed from predecessor research standard in the 1970s and first used more widely in university or development settings from 1981
  - ▣ Named after its position in the 7-layer OSI model
- Unlike DICOM, HL7 is closed commercialized standard maintained by Health Level Seven International Organization
  - ▣ Until late 2013, completely unavailable for quick review without paid membership of organization
  - ▣ Today, standards available for download, but only for personal use
  - ▣ Standard remains guarded in contrast to DICOM



# Function of HL7

- HL7 messages are text strings, formatted in very specific, defined, repeatable ways
- Each message has every possible 'field' either filled or left empty, separated by specific characters (known as delimiters)
- All possible data types for particular fields are defined by the standard
- Version 2 HL7 messages are intended for machine use and interpretation, rather than human manipulation

```
MSH|^~\&|MegaReg|DSNHSFT|ImgOrdMgr|RadImgCtr|20170115090131-  
0500||ADT^A01|01052901|P|2.8.2  
EVN||201701150901|||20170150900  
PID||56782445^^^UAREg^PI~999855750^^^USSSA^SS||ATKINSONTEST^JAMES  
^A^JNR||19800910|M||2028-9^^HL70005^RA9999^^XYZ|12ASEASHORE ROAD  
^^NEWPORT^DEVON^SS10 3AA^^H|||||0105130001^^^99DEF^AN  
PV1|||W^389^1^UABH^^^3||||1234567890^THILAKENDRAN^SUJENTHAR^S^^^MD^0010^UAMC^L||  
0123456789^MORTON^LINDSEY^A^^^MD^0010^UAMC^L|MED|||||A0||13579^  
HODGKINSON^JENNA^A^^^MD^0010^UAMC^L  
OBX|1|NM|^Body Height||1.85|m^Meter^ISO+|||||F  
OBX|2|NM|^Body Weight||85|kg^Kilogram^ISO+|||||F  
AL1|1||^CONTRAST AGENT
```

# HL7 Message Segments

- MSH (message header information)
  - ▣ Message delimiters (characters such as | ^ ~ \ & , which therefore cannot be used elsewhere in HL7 message text
    - For instance, 'A&E' is not permitted without modification in HL7 message
  - ▣ Origin and destination
  - ▣ Date and time
  - ▣ Message type (here, ADT) and trigger event (here, A01)
  - ▣ Message control ID
  - ▣ Processing ID
  - ▣ Version ID

```
MSH|^~\&|MegaReg|DSNHSFT|ImgOrdMgr|RadImgCtr|20170115090131-  
0500||ADT^A01|01052901|P|2.8.2
```

# HL7 Message Segments

- EVN (event information)
  - ▣ When the event was recorded
  - ▣ When the event occurred
  - ▣ Who was responsible
  - ▣ The event name
- PID (patient identification information)
  - ▣ Identifiers
  - ▣ Names and addresses
  - ▣ Date/time of birth
  - ▣ Gender, ethnic origin
  - ▣ Account numbers

```
EVN||201701150901|||20170150900
PID|||56782445^^^UAReg^PI~999855750^^^USSSA^SS||ATKINSONTEST^JAMES
^A^JNR||19800910|M||2028-9^^HL70005^RA9999^^XYZ|12ASEASHORE ROAD
^^NEWPORT^DEVON^SS10 3AA^^H|||||0105130001^^^99DEF^AN
```

# HL7 Message Segments

- PV1 (patient visit information)
  - ▣ Class (I/P or O/P)
  - ▣ Doctors (attending, consulting, referring, admitting)
  - ▣ Admit and discharge date and time
- OBX (observation information)
  - ▣ Data type of the observation
  - ▣ Name of the attribute being observed
  - ▣ Value and units
  - ▣ Observation status (such as preliminary or final)
- AL1 (allergy information)

- ▣ Severity

- ▣ Type

```
PV1|||W^389^1^UABH^^^^3|||1234567890^THILAKENDRAN^SUJENTHAR^S^^^MD^0010^UAMC^L||  
0123456789^MORTON^LINDSEY^A^^^MD^0010^UAMC^L|MED|||A0||13579^  
HODGKINSON^JENNA^A^^^MD^0010^UAMC^L  
OBX|1|NM|^Body Height||1.85|m^Meter^ISO+||||F  
OBX|2|NM|^Body Weight||85|kg^Kilogram^ISO+||||F  
AL1|1||^CONTRAST AGENT
```

# HL7 Message Types

- Type of message defined within header
  - ▣ over 50 types to choose from
- Messaging operates on 'read-back' confirmation basis
  - ▣ Prefix of ADT or ACK is appended depending on whether it is original instruction from requesting system, or confirmation response from receiving system
  - ▣ Example: message sent from MPI to RIS with ADT-A04 is instructing RIS to register patient, and RIS completes action requested and replies with identical message, except replacing with acknowledgement value in the message header: ACK-A04 to confirm action was done

Prefix	Value	Description
ADT or ACK	A01	Admit a patient/visit notification
ADT or ACK	A02	Transfer a patient
ADT or ACK	A03	Discharge a patient/end this visit
ADT or ACK	A04	Register a patient
ADT or ACK	A05	Pre-admit a patient
ADT or ACK	A06	Change an O/P to an I/P
ADT or ACK	A08	Update patient information/record
ADT or ACK	A11	Cancel admission of patient
ADT or ACK	A12	Cancel transfer of patient
ADT or ACK	A13	Cancel discharge of patient
ADT or ACK	A18	Merge patient information/record

ACK, acknowledging response; ADT, admit, discharge, or transfer

# Reference Material

- Alexander Peck, Clark's Essential PACS. RIS and Imaging Informatics, CRC Press, 2018.
  - ▣ Chapters 8, 9

