

DICOM: Definitions and Testing

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Acknowledgements

- Sam Brain, Stanford University
 - Stanford IMRT Short Course
- Committee to Advance DICOM
 - Slide Resources
- DICOM Working Group 7
 - Radiation Therapy Extensions

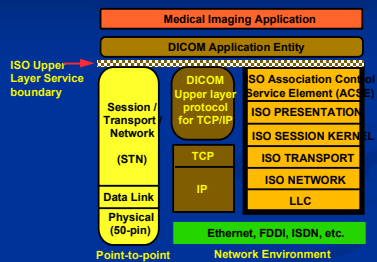
Objectives

- Introduction to 'DICOM-speak'
 - History of DICOM
 - Overview of Documentation
- DICOM Testing
 - Conformance Statements
 - DICOM 'Authorities'
 - Some useful DICOM Utilities
- Use of DICOM in National Protocols
- DICOM Connectathon

What is DICOM?

- Digital Imaging **CO**munications in **M**edicine
- Network/Communication Protocol
 - Designed for transfer of information
 - Initial shortcomings for storage, management
- Object-Oriented Model
 - Abstracts processes based on the data
 - Images, Plans, Structure Sets
 - Operators are actions that act on the data
 - Storage, Query, Print

Network Protocol



DICOM Features

- OBJECT DATA MODEL
 - DICOM is based on a completely specified data model
 - DICOM includes a robust UID mechanism
- DATA DICTIONARY
 - DICOM includes a large number of new data elements
- SERVICE CLASSES
 - DICOM defines classes of service for specific applications (e.g. image management, printing) and conformance levels

DICOM Features

- NETWORK PROTOCOL
 - DICOM incorporates *negotiation* to permit nodes to agree on the functions to be performed
- MESSAGE ENCODING
 - DICOM defines 24+ data types
 - DICOM message encoding includes JPEG compression
 - DICOM includes encapsulated image and multi-frame syntaxes
 - DICOM supports multiple character repertoires

DICOM Features

- Off-Line Media Support
 - DICOM defines a directory structure and media profiles
 - CD-ROM, DVD, ...
- Conformance
 - DICOM requires conformance statements and contains detailed conformance requirements
 - Means of Testing, establishing compatibility

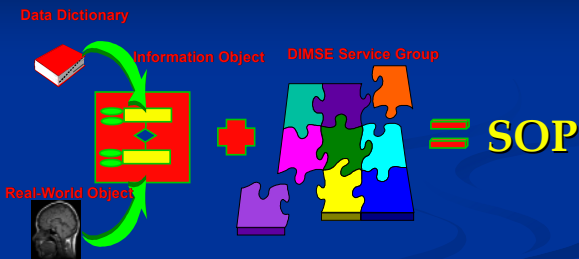
DICOM Terminology

- **DICOM Message Service Element (DIMSE)** - The set of DICOM Application Layer communication services.
- **DIMSE Service Group (DSG)** - A subset of the full DIMSE services which is applicable to a specific IOD.
- **Information Object Definition (IOD)** - A data abstraction of a class of real-world objects. A collection of related attributes (data elements).

DICOM Terminology

- **Service Class** - A set of functionality relating to a single type or real-world activity. Composed of a set of SOP Classes plus rules and associated semantics.
- **Service-Object-Pair Class (SOP)** - The atomic unit of DICOM functionality. Composed of an IOD and a DIMSE Service Group plus restrictions or extensions of the IOD. (Equivalent to an Object Class)

Service-Object Pair Class



DICOM Service Classes

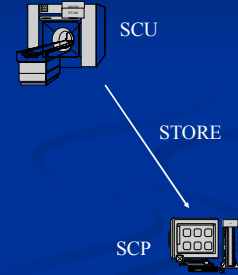
- Verification
- Storage
- Query/Retrieve
- Print Management
- Patient Management
- Study Management
- Results management
- Study Content Notification

DICOM Service Classes

- Verification (C-ECHO)
 - SCU (client) sends a C-ECHO request to SCP (server)
 - SCP replies with C-ECHO response back to SCU
 - DICOM equivalent of Unix “ping”, but occurs between DICOM AE’s

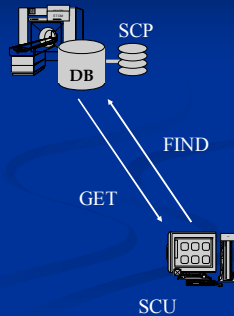
DICOM Service Classes

- Storage (C-STORE)
 - a.k.a. “push”
 - Transfer is initiated at the SCU (client)
 - SCP (server) stores DICOM objects on some medium (disk, etc.)



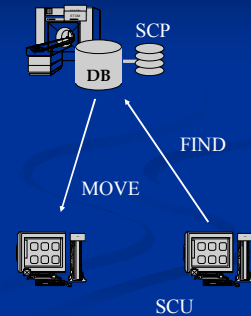
DICOM Service Classes

- Query/Retrieve
 - a.k.a. “pull”
 - Service has two parts
 - SCU makes a request for list of available objects (FIND)
 - SCU then requests the images transferred back to self (GET) or...



DICOM Service Classes

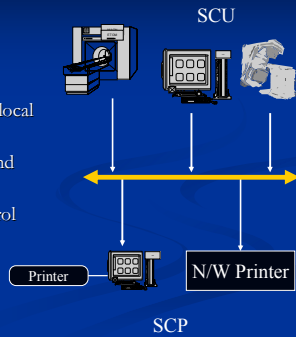
- Query/Retrieve
 - a.k.a. “pull”
 - Service has two parts
 - SCU makes a request for list of available objects (FIND)
 - SCU then requests the images transferred back to self (GET)...
 - ... or to another W/S (MOVE)



DICOM Service Classes

■ Print Management

- Prints to DICOM-capable N/W printer or W/S with local printer
- Allow printing of images and overlays
- Layout and gray scale control
- Queue management



How can I make DICOM work?

■ Configuration

- Application Entity Title (AETITLE)
 - Name for a DICOM Sender / Receiver
 - Maximum of 16 characters, typically all caps
- IP Address / Host Name
 - How to find the DICOM Application in TCP/IP Land
- Port
 - TCP/IP mechanism for defining/restricting access
 - DICOM can use any port, 104 is specifically allocated

What Happens in DICOM?

SERVICE CLASS USER (SCU)



SERVICE CLASS PROVIDER (SCP)



- Establish an Association
 - Location
 - Find IP/Host
 - Port must be active
- Negotiation
 - SOP Available
 - Data Formats
- Perform the Service
 - Transfer Data for Storage
- Close the Association

DICOM Communication



“Can you...?”

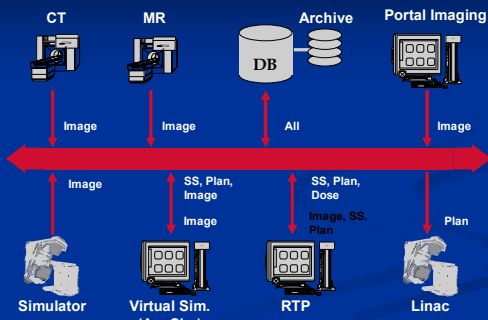


“Yes, I can.”

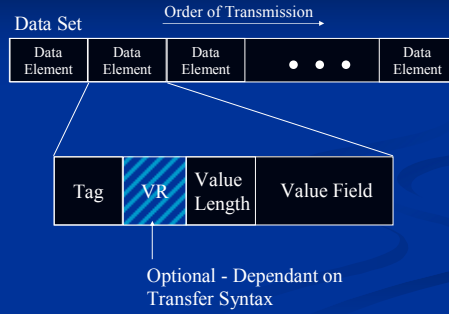
■ Network Data Transfer

- Negotiated syntax
 - Big/Little-endian
 - What Services are supported
 - JPEG Compression

Departmental Data Flows



DICOM Data Stream



DICOM Data Elements

- Name is unique label
 - (See Part 6)
- VR is data type
 - Defined in Part 5
- Tag is unique ID
 - (2) 4-digit (hex) numbers
 - Defined in Data Dictionary (See Part 6)
 - 1st number is group
 - Even is Standard
 - Odd is Private Extension

Table C.7.2.1 – General Study Module Attributes

Attribute Name	Tag	Type	Attribute Description
Study Instance UID	(0020,000D)	1	Unique identifier for the Study.
Study Date	(0008,0020)	2	Date the Study started.
Study Time	(0008,0030)	2	Time the Study started.
Referring Physician's Name	(0008,0090)	2	Patient's referring physician
Study ID	(0020,0010)	2	User or equipment generated Study identifier.
Accession Number	(0008,0050)	2	A RIS generated number which identifies the order for the Study.
Study Description	(0008,1030)	3	Institution-generated description or classification of the Study (component performed).
Name of Physician(s) Reading Study	(0008,1060)	3	Physician(s) reading the Study.

DICOM Tags

- Types
 - 1 Required, non-blank
 - 2 Required, can be blank
 - 3 Optional
- Description
 - Free text description of attribute

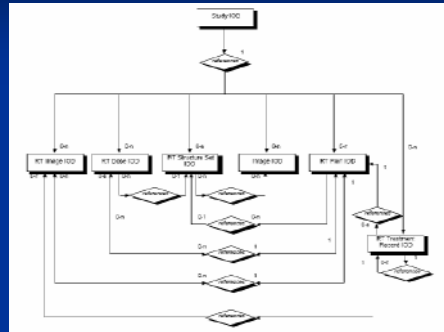
Table C.7.2.1 – General Study Module Attribute

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Name of Physician(s) Reading Study	(0008,1060)	3	Physician(s) reading the Study.

DICOM RT

- Proposed at RSNA, 1994
 - Working Group started in 1995 as NEMA RT Section TG
 - First objects approved in 1998
- Added several objects for Radiation Therapy
 - RT Dose
 - RT Structure Set
 - RT Image
 - RT Plan
 - RT Treatment Record(s)
- Since DICOM 3.1, just another part of DICOM

DICOM RT Objects



RT Image

- Conical Imaging Geometry
 - Conventional Simulators
 - Virtual Simulators (DRRs)
 - Portal Images

A.17.8 RT Image SOP Module Table

SC	Module	Element	Value
Patient	Patient	0.7.1.1	U
		0.7.1.2	U
		0.7.1.3	U
		0.7.1.4	U
Study	Study	0.7.2.1	U
		0.7.2.2	U
		0.7.2.3	U
		0.7.2.4	U
Series	Series	0.8.1.1	U
		0.8.1.2	U
Frame of Reference	Frame of Reference	0.7.3.1	U
		0.7.3.2	U
Image	Image	0.7.4.1	U
		0.7.4.2	U
		0.7.4.3	U
		0.7.4.4	C-Requires Protocol indication within this image
		0.7.4.5	C-Requires Protocol indication within this image
		0.7.4.6	C-Requires Protocol data to exist in this image
		0.7.4.7	U
		0.7.4.8	U
		0.7.4.9	U
		0.7.4.10	U
		0.7.4.11	U
		0.7.4.12	U

RT Series Module

Table C.8-33 - RT SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0005)	1	Type of equipment that originally acquired the data. Enumerated Values: RT IMAGE = RT Image RTDOSE = RT Dose RTSTRUCT = RT Structure Set RTPLAN = RT Plan RTRECORD = RT Treatment Record See C.8.8.1.1.
Series Instance UID	(0020,000E)	1	Unique identifier of the series.
Series Number	(0020,0011)	2	A number that identifies the series.
Series Description	(0008,103E)	3	User provided description of the series.
Referenced Performed Procedure Step Sequence	(0008,1111)	3	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related (e.g. a Modality or General-Purpose Performed Procedure Step SOP Instance or Study Component SOP Instance). One or more items may be included in this sequence.
Referenced SOP Class UID	(0008,1105)	1C	Uniquely identifies the referenced SOP Class. Required if Referenced Performed Procedure Step Sequence (0008,1111) is set.

RT Dose

- Radiotherapy Dose Distributions
 - 2- and 3-D Dose Grids
 - Named or Unnamed Dose Points
 - Isodose Curves
 - Dose-Volume Histograms

A.18.1 RT Dose IOD Module Table
Table A.18.1.1-RT Dose IOD Modules

ID	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
	General Study	C.7.1.1	U
Study	Patient Study	C.7.2.1	M
	Clinical Trial Study	C.7.2.3	U
	General Study	C.7.2.1	U
Series	RT Series	C.8.1.1	M
	Clinical Trial Series	C.8.1.3	U
Frame of Reference	Frame of Reference	C.7.6.1	M
	General Frame	C.7.6.2	U
Dose	Image Plane	C.7.6.2	C - Requires Frame data contains ignored dose
	Image Plan	C.7.6.3	C - Requires Frame data contains ignored dose
	MultiFrame	C.7.6.8	C - Requires Frame data contains ignored dose and non-zero isodose data
	Dose Point	C.8.2	U
	MultiFrame Dose	C.8.3	U
	Intensity LUT	C.11.1	U
	RT Plan	C.8.8.3	M
	RT Dose	C.8.8.8	U
	Structure Set	C.8.8.8	C - Requires Frame data contains dose points in Structure Set
	ROI Contour	C.8.8.8	C - Requires Frame data contains dose points in Structure Set
RT Dose ROI	C.8.8.7	C - Requires Frame data contains dose points in Structure Set	
Audio	C.13.3	U	
DOP Contour	C.12.1	U	

RT Structure Set

- Defines Radiotherapy-Related Structures
 - Anatomical outlines, target volumes, critical structures
 - Isodose lines, reference point doses
- May reference CT or MR images

A.18.3 RT Structure Set IOD Module Table
Table A.18.3.1-RT Structure Set IOD Modules

ID	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.1	U
Series	Clinical Trial Series	C.8.1.3	U
	RT Series	C.8.1.1	M
Equipment	General Equipment	C.7.6.1	M
	RT Equipment	C.8.8.1	M
Structure Set	Structure Set	C.8.8.1	M
	ROI Contour	C.8.8.8	M
	RT ROI Observations	C.8.8.8	M
	Audio	C.8.8.16	U
Audio	Audio	C.13.3	U
	DOP Contour	C.12.1	M

RT Treatment Record

- Delivery Record
- Defines Three New IODs:
 - RT Beams Treatment Record
 - RT Brachytherapy Treatment Record
 - RT Treatment Summary Record

A.18.4 RT Beams Treatment Record IOD Module Table
Table A.18.4.1-RT Beams Treatment Record IOD Modules

ID	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
	General Study	C.7.2.1	M
Study	Patient Study	C.7.2.1	M
	Clinical Trial Study	C.7.2.3	U
	General Study	C.7.2.1	U
Series	RT Series	C.8.1.1	M
	Clinical Trial Series	C.8.1.3	U
Treatment Record	RT Beams Treatment Record	C.8.8.17	M
	RT Brachytherapy Treatment Record	C.8.8.18	U
Equipment	General Equipment	C.7.6.1	M
	RT Treatment Machine	C.8.8.18	M
Dose	Measured Dose Reference Record	C.8.8.18	U
	Calculated Dose Reference Record	C.8.8.20	M
Audio	RT Beams Session Record	C.8.8.21	M
	RT Treatment Summary Record	C.8.8.23	U
Audio	Audio	C.13.3	U
	DOP Contour	C.12.1	M

RT Plan

- Contains Modules for
 - Prescription
 - Patient Setup
 - Fractionation
 - External Beam Treatment
 - Brachytherapy Treatment

A.18.5 RT Plan IOD Module Table
Table A.18.5.1-RT Plan IOD Modules

ID	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
	General Study	C.7.2.1	U
Study	General Study	C.7.2.1	U
	Patient Study	C.7.2.1	M
	Clinical Trial Study	C.7.2.3	U
Series	RT Series	C.8.1.1	U
	Clinical Trial Series	C.8.1.3	U
Frame of Reference	Frame of Reference	C.7.6.1	U = Dev Note
	General Frame	C.7.6.2	U
Plan	RT Treatment Plan	C.8.8.9	U
	RT Prescription	C.8.8.10	U
	RT Prescription Tables	C.8.8.11	U
	RT Patient Setup	C.8.8.12	U
	RT Brachytherapy	C.8.8.13	U
RT Beams	RT Beams	C.8.8.14	C - Requires RT Prescription, Structure and number of Beams (BEAM-SSB) is greater than zero for use in most fractionation
	RT Brachytherapy Dose	C.8.8.14	C - Requires RT Prescription, Structure, Module Beam and number of Beams (BEAM-SSB) is greater than zero for use in most fractionation
Audio	Audio	C.13.3	U
	DOP Contour	C.12.1	U

RT Beams Module

- Beam
 - Beam Name
 - Radiation Type
 - Beam Limiting Device (MLC, Collim.)
 - Wedge
 - Compensator
 - Bolus
 - Block
 - Applicator
- # of Control Points
- Control Point
 - Beam Energy
 - Gantry Angle, Rotation Direction
 - Collimator Settings
 - MLC Positions
- Control Point

Control Point Sequence

- Flexible Enough to Handle:
 - Static Beams, including static MLC
 - Arcs
 - Dynamic MLC
- Uses “Cumulative Meterset Weight” concept
 - Portion of the beam delivered in segment

Control Point Sequence

- Control Point 0;
 - Cumulative Meterset Weight = 0
 - Defines all initial parameters
 - Gantry, table, collimator/MLC settings, etc.
- Subsequent Control Points
 - Cumulative Meterset Weight > 0
 - Specify all parameters which change

Control Point Sequence

- Static Beam
 - Control Point 0:
 - Cumulative Meterset Weight = 0
 - Define Gantry, Table, Collimator, MLC, etc...
 - Control Point 1:
 - Cumulative Meterset Weight = 1
 - (No other parameters defined)

Control Point Sequence

- Arc Beam
 - Control Point 0:
 - Cumulative Meterset Weight = 0
 - Gantry Angle = θ_i
 - Gantry Rotation Direction = CW/CCW
 - All other Parameters (collimator, table, ...)
 - Control Point 1:
 - Cumulative Meterset Weight = 1
 - Gantry Angle = θ_f
 - Gantry Rotation Direction = NONE

Control Point Sequence

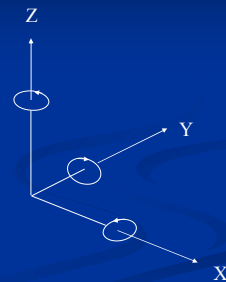
- Dynamic MLC, N Segments
 - Control Point 0:
 - Cumulative Meterset Weight = 0
 - Initial MLC Leaf Sequence \mathcal{S}_0
 - All other parameters
 - Control Point 1:
 - Cumulative Meterset Weight = $1/N$
 - MLC Leaf Sequence \mathcal{S}_1

Control Point Sequence

- Dynamic MLC, N Segments (continued)
 - Control Point r :
 - Cumulative Meterset Weight = r/N
 - MLC Leaf Sequence \mathcal{S}_r
 - ...
 - Control Point N :
 - Cumulative Meterset Weight = 1
 - MLC Leaf Sequence \mathcal{S}_N

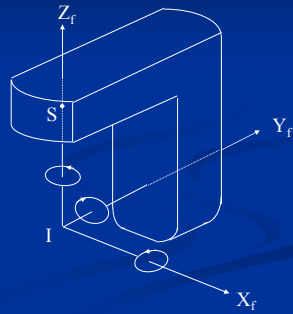
DICOM RT Coordinate System

- IEC 1217
- Right-handed
- Positive rotations CW looking along +ve axis
- Zero angle is nominal (unrotated) position
- Defines Series of Coordinate Systems:
 - Fixed, Gantry, Collimator, Wedge, Table, ...



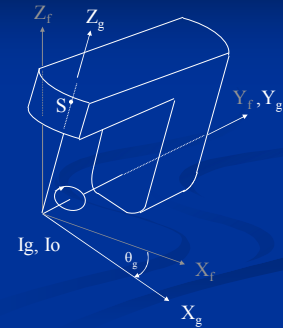
Coordinate Systems

- Fixed System
 - Origin at Isocenter
 - Z-axis vertical
 - Y-axis co-linear with rotation axis of gantry
 - X-axis at right angles to Y, Z

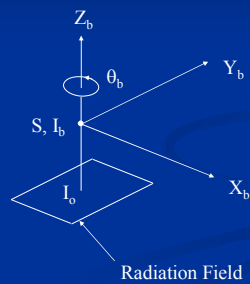


Gantry Coordinate System

- Stationary w.r.t. Gantry. Z_g -axis passes thro radiation source S
- Derived from Fixed Coordinate System by rotation about Y-axis

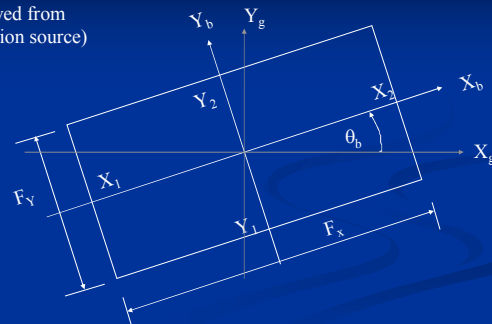


Beam Limiting Device Coordinate System



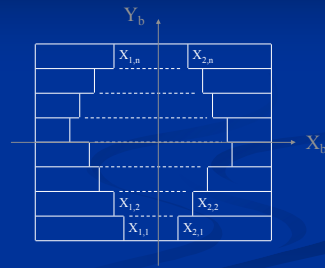
Collimator Rotations

(Viewed from radiation source)



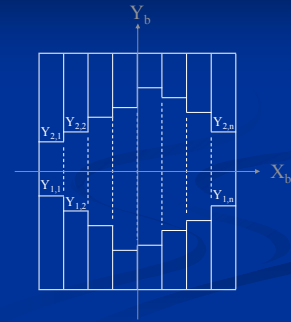
MLC-X Positions

- Leaf Positions are mechanical boundaries projected onto Isocenter plane
- Positions sent in order
 $X_{1,1}, X_{1,2}, \dots, X_{1,N},$
 $X_{2,1}, X_{2,2}, \dots, X_{2,N}$



MLC-Y Positions

- Leaf Positions sent in order
 $Y_{1,1}, Y_{1,2}, \dots, Y_{1,N},$
 $Y_{2,1}, Y_{2,2}, \dots, Y_{2,N}$



DICOM 3 Parts

- | | |
|-----------------------------------|--|
| 1. Introduction and Overview | 10. Media Storage and File Format |
| 2. Conformance | 11. Media Storage Application Profiles |
| 3. Information Object Definitions | 12. Physical Media Formats |
| 4. Service Class Specifications | 13. (Retired) |
| 5. Data Structures & Semantics | 14. Grayscale Display Standard |
| 6. Data Dictionary | 15. Security |
| 7. Message Exchange | 16. Content Mapping |
| 8. Network Communication Support | |
| 9. (Retired) | |

<http://medical.nema.org/dicom/2003.html>

Conformance

- DICOM Part 2 specifies the structure of a conformance statement
- DICOM does not specify a test suite or a compliance verification mechanism
- All DICOM implementations must be supported by a properly constructed conformance statement

DICOM Conformance Statement

- Implementation Model which describes the Application Entities in the implementation
- Detailed specification of each Application Entity
 - SOP Classes supported
 - policies for initiation and acceptance of associations
- Presentation Contexts
- SOP options
- Supported communications protocols
- Specializations
- Configuration

Purpose of a Conformance Statement

- Allow a user to determine which optional components of the DICOM Standard are supported by a particular implementation, and what extensions or specializations an implementation adds.
- By comparing the Conformance Statements from two implementations, a **knowledgeable** user **should** be able to determine whether or not interoperability is possible.

DICOM Conformance Testing

- No Formal Mechanism is Defined in the Standard
- Committee for the Advancement of DICOM
- Define initial test plan and cross-connect matrix
- Future RFP for organization to monitor the process
- Problem: How to Map DICOM Conformance Statements into Test Plans

DICOM Testing -- DICOMWorks

Single editor (Unlinked editor)

List all tags found in file: @ tags displayed / total=66 tags

	Group/Element	Title	Value
	Vendor tags		
	Colocal tags		
	File Meta Elements	File Meta Elements Group Length	1
		File Meta Information Version	1
	Study Information	Media Storage SOP Class UID	1.2.840.10008.1.2.1
		Media Storage SOP Instance UID	1.2.840.10008.1.2.1
	File Meta	Transfer Syntax UID	1.2.840.10008.1.2.1
	Acquisition Group	Implementation Class UID	1.2.840.10008.1.2.1
	Relationship Group	Implementation Version Name	ETNAI_DC4111_361
	Image presentation	Image Type	DERIVEDSECONDARY
	Private	SOP Class UID	1.2.840.10008.1.2.1
		SOP Instance UID	1.2.840.10008.1.2.1
	Tags to modify	Study Date	20040701
	Tags to add	Study Time	120000
	Tags to remove	Accession Number	
	Search	Modality	1.2.840.10008.1.2.1

<http://dicom.online.fr/>

