

Hi•ART System[®]

DICOM CONFORMANCE STATEMENT

VERSION 3.X

100534 A





DICOM Conformance Statement

TomoTherapy HI·ART System[®]

HI·ART 3.X Release

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Privacy Statement

TomoTherapy Incorporated is committed to providing medical equipment that helps customers to be compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). The following specific features and design measures have been incorporated into the TomoTherapy HI•ART System® to facilitate this:

- The TomoTherapy Hi•Art® network is physically distinct and has a single point of connection to the rest of the institution's network.
- The point of connection between the facility and TomoTherapy Hi•Art networks is protected by a firewall device, typically configured to allow only specific, controlled forms of network traffic (for example, DICOM import).
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- A user-level screen lock capability is provided on TomoTherapy HI•ART workstations.

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The TomoTherapy Hi•Art System, including each computer workstation and associated system software, has been extensively validated to demonstrate that the system will perform as expected. The installation of additional software not released by TomoTherapy Incorporated (e.g. third party, off the shelf, etc.) on these computer workstations is not permitted. This includes any Microsoft Windows updates. Any effect on the safe and intended operation of the Hi•Art system caused by the introduction of additional software is unknown and TomoTherapy cannot be

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- TomoTherapy Incorporated respects customer and patient confidentiality in accordance with the Health Insurance Portability and Accountability Act of 1996 (HIPAA). TomoTherapy Incorporated will not use retrieved files for purposes other than to provide system support for the customer.

Instructions for Use of the Hi•Art System

TomoTherapy user documentation applies to safe and effective use of the Hi•Art System by educated dosimetrists, therapists, and physicists. Personnel must be trained by TomoTherapy Incorporated before the Hi•Art System is used for research or clinical purposes. TomoTherapy Hi•Art System documentation was originally drafted, approved and supplied in English (U.S.).

The following statements are intended to alert the user to potential conditions that could result in injury to the patient (warning) or conditions that could affect system components (caution).



Warning Warning statements describe possible conditions that can result in serious or fatal injury to the patient or facility personnel. Each warning gives the possible condition and how to avoid it.



Caution Caution statements describe possible conditions that can affect system performance or cause damage to system components. Each caution gives the possible condition and how to avoid it

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1 Conformance Statement Overview

This document specifies the compliance to DICOM conformance requirements for the relevant networking features on TomoTherapy Incorporated's HI·ART System. The TomoTherapy HI·ART System[®] requires HI·ART 3.X Release software as a minimum for this Conformance Statement to apply.

Table 1. Network Services

Networking SOP Classes	User of Service (SCU)	Provider of Service (SCP)
Object Storage		
CT Image Storage	Yes	Yes
RT Structure Set Storage	Yes	Yes
RT Dose Storage	Yes	—
RT Plan Storage	Yes	—

NOTE: Support for some of these services may be separately licensable options. Details about licensable options can be found in TomoTherapy marketing and sales documentation.

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3 Introduction

3.1 Audience

The reader of this document is concerned with software design and/or system integration issues. It is assumed that the reader of this document is familiar with the DICOM Standards and with the terminology and concepts that are used in those Standards.

If readers are unfamiliar with DICOM terminology they should read the DICOM Standard before reading this Conformance Statement document.

3.2 Remarks

The use of this DICOM Conformance Statement, in conjunction with the DICOM v3.X Standards, is intended to facilitate communication with TomoTherapy HI-ART equipment. However, by itself, it is not sufficient to ensure that inter-operation will be successful. The user (or user's agent) needs to proceed with caution and address at least four issues:

- **Integration:** The integration of any device into an overall system of interconnected devices goes beyond the scope of standards (DICOM v3.X), and of this DICOM Conformance Statement when interoperability with non-TomoTherapy equipment is desired. The responsibility to analyze the applications requirements and to design a solution that integrates TomoTherapy equipment with non-TomoTherapy systems is the user's responsibility and should not be underestimated. The user is strongly advised to ensure that such an integration analysis is correctly performed.
- **Validation:** Testing the complete range of possible interactions between the TomoTherapy HI-ART System and non-TomoTherapy devices, before the connection is declared operational, should not be overlooked. Therefore, the user should ensure that any non-TomoTherapy provider accepts full responsibility for all validation required for their connection with the TomoTherapy HI-ART System. This includes the accuracy of the image data once it has crossed the interface between the HI-ART System and the non-TomoTherapy device and the stability of the image for the intended applications.

Such a validation is required before any clinical use (treatment planning and/or delivery) is performed. It applies when images acquired on non-TomoTherapy imaging equipment are processed/displayed on a HI-ART workstation, and when images are exported from the TomoTherapy HI-ART System to a non-TomoTherapy device.

- **Future Evolution:** TomoTherapy understands that the DICOM Standard will evolve to meet the user's growing requirements. TomoTherapy is actively involved in the development of the DICOM v3.X Standard. DICOM v3.X will incorporate new features and technologies and TomoTherapy may follow the evolution of the Standard. Evolution of the Standard may require changes to the TomoTherapy HI-ART System. In addition, TomoTherapy reserves the right to discontinue or make changes to the support of communications features (on its products) reflected on by this DICOM Conformance Statement. The user should ensure that any non-TomoTherapy provider, which connects with the TomoTherapy HI-ART System, also plans for the future evolution of the DICOM Standard. Failure to do so will likely result in the loss of function and/or connectivity as the DICOM Standard changes and the HI-ART System is enhanced to support these changes.

- **Interaction:** It is the sole responsibility of the non-TomoTherapy provider to ensure that communication with the interfaced equipment does not cause degradation of TomoTherapy Hi-ART System performance and/or function.

3.3 Definitions, Terms, and Abbreviations

AE	Application Entity
DICOM	Digital Imaging and Communications in Medicine
IMS	Information Management System
SCP	Service Class Provider
SCU	Service Class User
SOP	Service-Object Pair
TCP/IP	Transmission Control Protocol/Internet Protocol
UID	Unique Identifier

3.4 References

- Digital Imaging and Communications in Medicine (DICOM), NEMA PS 3.1-3.18, 2007

4 Networking

4.1 Implementation Model

4.1.1 Application Data Flow

Two diagrams illustrate the application model, one for TomoProvider in the SCP role and one for TomoUser in the SCU role.

4.1.1.1 TomoProvider (SCP) Application Data Flow Diagram

This implementation model provides for import of DICOM-compatible CT Images and RT Structure Sets from an external system. The external DICOM-compliant system, acting as a Service Class User (SCU), initiates the transfer to the TomoProvider Application Entity using the DICOM Storage Service Class. The TomoProvider Application Entity, which is a Service Class Provider (SCP), responds dynamically to receive the data and prepares them for storage in a format that complies with TomoTherapy protocols. The TomoProvider also supports the ECHO protocol for externally initiated verification sequences. As such, no local operator action is necessary to receive data.

The TomoProvider Application Entity is invoked by the following real-world activities:

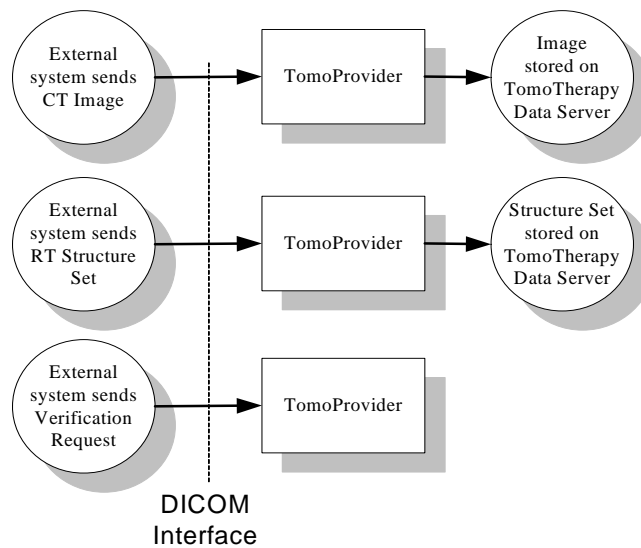


Figure 1: TomoProvider (SCP) Application Data Flow Diagram

4.1.1.2 TomoUser (SCU) Application Data Flow Diagram

This implementation model provides for export of DICOM-compatible CT image and TomoImage sets, RT Structure Set objects, RT Dose objects and RT Plan objects to an external system using the corresponding DICOM Information Object Definitions (IODs). The TomoUser Application Entity is invoked by the following real-world activities:

Export: The user initiates a DICOM transfer to an external system from the HI-ART workstation. The workstation generates a request to the TomoUser Application Entity, containing information identifying the TomoTherapy database object to be transmitted to the external system. The TomoUser Application Entity, acting as a Service Class User (SCU), initiates the transfer to the external DICOM-compliant system, using the appropriate DICOM Storage Service Classes. The data are conditioned from TomoTherapy data into DICOM-compliant data at send time.

Verification: The user initiates a DICOM Verification from the HI-ART workstation to an external system. The workstation generates a request to the TomoUser server. This request initiates the C-ECHO on the TomoUser server to the external system.

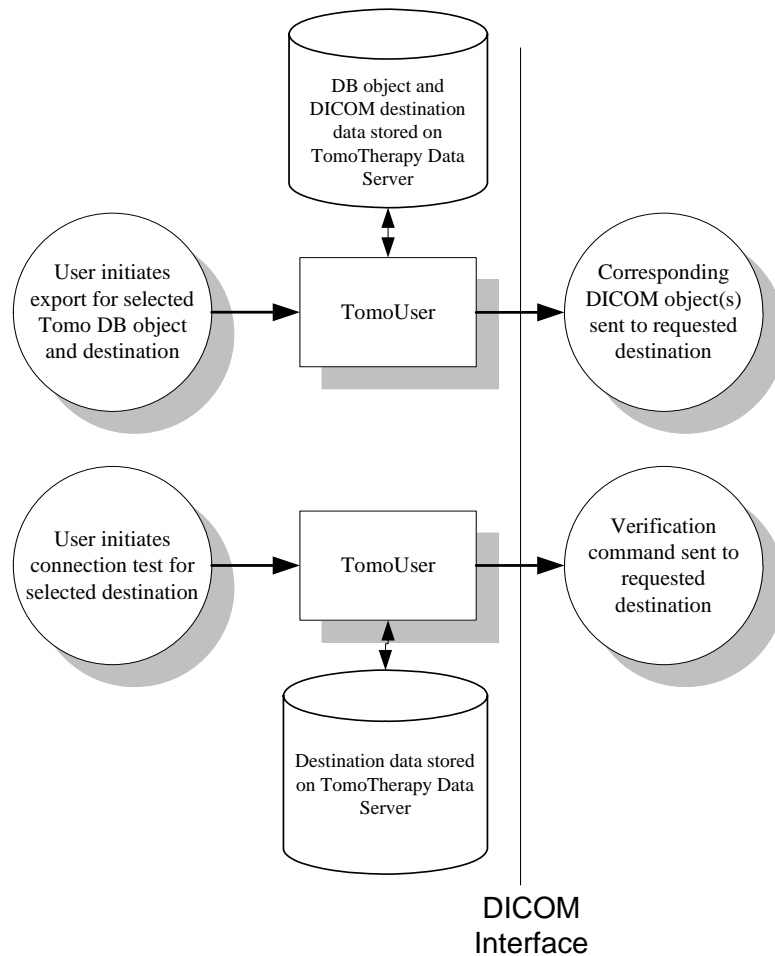


Figure 2: TomoUser (SCU) Application Flow Diagram

4.1.2 Functional Definition of AEs

4.1.2.1 Functional Definition of Storage SCP Application Entity

The *TomoProvider* Application Entity resides on the TomoTherapy Data Server machine. It starts when the station on which it resides is brought up, and runs continuously until the station is brought down. After initialization, TomoProvider waits for an association request at the port address configured for its Application Entity Title. When an external system requests an association, TomoProvider checks the presentation and application contexts to see if a valid context has been proposed. After a valid context is proposed and TomoProvider accepts the association, it waits for C-ECHO and C-STORE commands from the external system. TomoProvider maintains the association until the external system initiates the release process or initiates an abort.

4.1.2.2 Functional Definition of Storage SCU Application Entity

The *TomoUser* Application Entity resides on the TomoTherapy Data Server machine. It starts when the station on which it resides is brought up, and runs continuously until the station is brought down. After initialization, TomoUser waits for a user request from a HI-ART workstation. This request specifies the AE Title, port, and address for the association. TomoUser constructs a context and proposes it to the SCP. If accepted, it then attempts the requested operation. If the requested operation is a C-ECHO, it verifies the connection. If the requested operation is a C-STORE, it performs the appropriate C-STORE commands until all objects are transmitted or a failure is received.

4.1.3 Sequencing of Real-World Activities

4.1.3.1 TomoProvider (Storage SCP) Sequencing

If the external system acting as an SCU sends the CT Image series and associated (referencing) RT Structure Set(s) to TomoProvider in separate associations, then the CT Image must precede the RT Structure Set(s).

For an external system acting as an SCU, all CT Image objects of interest in a given CT series must be sent to TomoProvider in a single association, i.e. a second set of images belonging to an existing series cannot be appended to the initial series.

If multiple objects are sent to TomoProvider within the same association, the sequencing of those objects within the association is not relevant.

4.1.3.2 TomoUser (Storage SCU) Sequencing

Under normal workflow conditions the following sequencing constraints apply:

- TomoTherapy Data Server entities can be selected and transmitted via DICOM in any order. However, it is usual to export diagnostic CT image sets (if required) before plan and dose information.
- Diagnostic CT information or TomoImage information can be sent at any time. Both image types use the standard CT Image IOD.

- A TomoTherapy Plan and its associated (plan-level) structure set are selected and exported independently. The RT Plan and RT Structure Set information cannot be sent until the corresponding TomoTherapy treatment plan has been approved (i.e. 'Final Accept' has been performed on the TomoTherapy Planning Station).
- When a disease-level (imported) structure set is selected, only an RT Structure Set object is sent. It does not require the existence of corresponding plans, approved or otherwise.
- When dose information is selected, only an RT Dose object is sent. The dose information cannot be sent until the corresponding treatment plan has been approved (i.e. 'Final Accept' has been performed on the TomoTherapy Planning Station).

4.2 AE Specifications

4.2.1 Storage SCP (TomoProvider) Application Entity Specification

4.2.1.1 SOP Classes

TomoProvider provides Standard Conformance to the following DICOM v3.X SOP Classes as an SCP. TomoProvider never acts in the role of an SCU.

Table 2. SOP Classes for TomoProvider Storage

SOP Class	SOP Class UID
CT Image Storage	1.2.840.10008.5.1.4.1.1.2
RT Structure Set Storage	1.2.840.10008.5.1.4.1.1.481.3
Verification	1.2.840.10008.1.1

4.2.1.2 Association Establishment Policy

4.2.1.2.1 General

The standard application context name for DICOM 3.X is always proposed:

Table 3. DICOM Application Context for TomoProvider Storage

Application Context Name	1.2.840.10008.3.1.1.1
--------------------------	-----------------------

TomoProvider is started as a service on the TomoTherapy Data Server PC approximately one minute after the Data Server initializes. After initializing, TomoProvider waits for association requests. When a successful association is made, a new thread is started to handle requests on the association. This process will receive one request at a time, process it, and send a response before reading the next request from the external system. The process will close the association if it has been idle for more than the configured time, if an unrecoverable error is reported, or if the Service Class User releases the connection.

TomoProvider does not place any restrictions on the maximum PDU size received from the sending SCU.

TomoProvider sets its maximum PDU size to 8192.

4.2.1.2.2 Number of Associations

TomoProvider places no limits on the number of concurrent associations. All transfers of a single image series must be performed using the same association.

Table 4. Number of Associations Accepted for TomoProvider Storage

Maximum number of simultaneous associations	No limit
---	----------

4.2.1.2.3 Asynchronous Nature

Although there may be concurrent associations, objects are processed in a serial fashion. TomoProvider processes each object in turn and sends a response before processing the next object. Therefore, there is no asynchronous activity in this implementation.

Table 5. Asynchronous Nature as an SCP for TomoProvider Storage

Maximum number of outstanding asynchronous transactions	1
---	---

4.2.1.2.4 Implementation Identifying Information

The implementation information for this application entity is:

Table 6. DICOM Implementation Information for TomoProvider Storage

SOP Class	SOP Class UID
Implementation Class UID	1.2.826.0.1.3680043.2.200.1
Implementation Version Name	3.X.x.xxx depending upon build version

4.2.1.3 Association Initiation Policy

TomoProvider does not initiate any associations.

4.2.1.4 Association Acceptance Policy

The following Real World Activities may establish an association with the TomoProvider:

- The external system requests storage for a CT Image Series and associated RT Structure Set(s) in the same association.
- The external system requests storage for a CT Image Series in one association, then RT Structure Set(s) in one or more separate associations.
- The external system requests storage for multiple related objects, one or more of which include an abstract syntax that is accepted but not stored.

The TomoProvider acts the same way in making the association for each of these cases, so the association acceptance policy for all of these real world activities is grouped in "Receive Objects" below.

4.2.1.4.1 Activity — Receive Objects

4.2.1.4.1.1 Description & Sequencing of Activities

The Associated Real-World Activity is an attempt by an external system to connect to the TomoProvider for CT Image or RT Structure Set storage.

4.2.1.4.1.2 Accepted Presentation Contexts

The table below indicates which presentation contexts the TomoProvider will accept. The IODs RT Image, RT Dose, and RT Plan are accepted but not processed by the TomoProvider AE, i.e. the presence of these objects in an association will be ignored but will not cause the DICOM transfer to fail.

Table 7. Acceptable Presentation Contexts for Receive Objects

Presentation Context Table					
Abstract Syntax		Transfer Syntax		Role	Ext Neg
Name	SOP Class UID	Name List	UID List		
CT Image Storage	1.2.840.10008.5.1.4.1.1.2	DICOM Implicit VR Little Endian	1.2.840.10008.1.2	SCP	None
RT Image Storage *	1.2.840.10008.5.1.4.1.1.481.1				
RT Dose Storage *	1.2.840.10008.5.1.4.1.1.481.2				
RT Structure Set Storage	1.2.840.10008.5.1.4.1.1.481.3				
RT Plan Storage *	1.2.840.10008.5.1.4.1.1.481.5				

NOTE 1: * denotes that object is not processed by application

NOTE 2: Support for some of these services may be separately licensable options. Details about licensable options can be found in TomoTherapy marketing and sales documentation.

4.2.1.4.1.3 Conformance for all Storage SOP Classes

TomoProvider will return one of the following error statuses when the C-STORE command is not successful.

Table 8. Error Statuses (all Storage SOP Classes)

Status Code	Meaning	Remedy
0110	Processing failure	Examine reason code, fix problem, and retransmit
0118	Unknown SOP Class	A command with an unknown SOP class was received; examine operation attempted

Status Code	Meaning	Remedy
		on SCU and retry as appropriate.
0120	A required field was not present	Review attribute field in error response to identify missing attribute. Correct problem and retry.
0210	Duplicate instance	Image/RT Structure Set already received successfully
0211	Unrecognized operation	An invalid data command, SOP Instance, or other corruption was detected; retransmit.
0213	Resource limitation	Memory problem in server; database table full; identify particular problem and see appropriate documentation for resolution.
C001	Cannot understand	The given combination of elements, and/or its conjunction with the referenced CT image does not satisfy the required conditions

4.2.1.4.1.4 SOP Specific Conformance for CT Image Storage and RT Structure Set Storage Classes

TomoProvider provides Level 0 Conformance to the C-STORE operations (local). Each SOP Class saves a particular subset of attributes (identified in Annex 8.1) from the transmission. All other attributes are discarded. When the C-STORE operation is successful, the CT Image or RT Structure Set is normally written to the Data Server. In the event that data is not written to the Data Server, the reason for failure will be identified in the Tomo Event Log facility as described in Section 4.4.1.2.

The data received by TomoProvider is accessible through the Planning Station software included with the TomoTherapy Hi-ART System. TomoProvider does not delete any data that it stores. Planning Station and Operator Station users determine its persistence duration.

Additional SOP-specific error codes are identified in the following table:

Table 9. Error Statuses (CT Image Storage or RT Structure Set Storage SOP Classes)

Status Code	Meaning	Remedy
0111	Duplicate instance	Image/RT Structure Set already received successfully
0210	Duplicate invocation	Image/RT Structure Set already received successfully

4.2.1.4.1.5 SOP Specific Conformance for Verification Class

TomoProvider provides standard conformance to the DICOM Verification Class as a Service Class Provider.

4.2.1.4.1.6 Presentation Context Acceptance Criterion

TomoProvider will always accept a Presentation Context for the Verification SOP Class with the DICOM Default Transfer Syntax. Additionally, TomoProvider will accept up to five of the above-mentioned Presentation Contexts on an association with the DICOM Default Transfer Syntax.

4.2.1.4.1.7 Transfer Syntax Selection Policies

TomoProvider accepts only the DICOM default transfer syntax.

4.2.2 Storage SCU (TomoUser) Application Entity Specification

4.2.2.1 SOP Classes

TomoUser provides Standard Conformance to the following DICOM v3.X SOP Classes as an SCU. TomoUser never acts in the role of an SCP.

Table 10. SOP Classes for TomoUser Storage

SOP Class	SOP Class UID
CT Image Storage (for diagnostic images and TomoImages)	1.2.840.10008.5.1.4.1.1.2
RT Structure Set Storage	1.2.840.10008.5.1.4.1.1.481.3
RT Dose Storage	1.2.840.10008.5.1.4.1.1.481.2
RT Plan Storage	1.2.840.10008.5.1.4.1.1.481.5
Verification	1.2.840.10008.1.1

NOTE: Support for some of these services may be separately licensable options. Details about licensable options can be found in TomoTherapy marketing and sales documentation.

4.2.2.2 Association Establishment Policy

4.2.2.2.1 General

The standard application context name for DICOM 3.X is always proposed:

Table 11. DICOM Application Context for TomoUser Storage

Application Context Name	1.2.840.10008.3.1.1.1
--------------------------	-----------------------

TomoUser operates as an SCU server, available at all times to service Workstation User requests. A user initiates a DICOM export activity. The workstation software constructs a request with the user data and transmits it to the TomoUser server. While the TomoUser server is performing the request, the workstation software periodically queries the TomoUser server for current transmission status. If the TomoUser completes the transaction successfully, the Export icon is dismissed from the desktop. If the TomoUser server completes the transaction unsuccessfully, the Export icon is available to the user to report the full history of the specific request.

TomoUser does not place any restrictions on the maximum PDU size received from the sending SCP.

TomoUser sets its maximum PDU size to the size configured for the particular DICOM destination involved in the association.

4.2.2.2.2 Number of Associations

TomoUser initiates only one association at a time. Subsequent requests are queued pending completion of the current operation.

Table 12. Number of Associations Proposed for TomoUser Storage

Maximum number of simultaneous associations	1
---	---

4.2.2.2.3 Asynchronous Nature

All TomoUser activities are performed synchronously. However, TomoUser activities are asynchronous with respect to the TomoTherapy HI-ART System itself (transfer activity does not block operation of the HI-ART System).

Table 13. Asynchronous Nature as an SCU for TomoUser Storage

Maximum number of outstanding asynchronous transactions	1
---	---

4.2.2.2.4 Implementation Identifying Information

The implementation information for this application entity is:

Table 14. DICOM Implementation Information for TomoUser Storage

SOP Class	SOP Class UID
Implementation Class UID	1.2.826.0.1.3680043.2.200.1
Implementation Version Name	3.X.x.xxx depending upon build version

4.2.2.3 Association Initiation Policy

TomoUser initiates an association upon receiving a request from the Workstation software. The initiation occurs based on one of two real-world activities:

- Workstation user tests an external destination.
- Workstation user pushes one or more of the supported entities to an external destination.

4.2.2.3.1 Activity — Send Objects

4.2.2.3.1.1 Description & Sequencing of Activities

The Associated Real-World Activity is an attempt by a TomoTherapy application to connect to the TomoUser AE to initiate storage of a supported object at an external storage SCP.

4.2.2.3.1.2 Proposed Presentation Contexts

The table below indicates which presentation contexts the TomoUser may propose to the storage SCP.

Table 15. Proposed Presentation Contexts for Send Objects

Presentation Context Table					
Abstract Syntax		Transfer Syntax		Role	Ext Neg
Name	SOP Class UID	Name List	UID List		
CT Image Storage	1.2.840.10008.5.1.4.1.1.2	DICOM Implicit VR Little Endian	1.2.840.10008.1.2	SCU	None
RT Dose Storage	1.2.840.10008.5.1.4.1.1.481.2				
RT Structure Set Storage	1.2.840.10008.5.1.4.1.1.481.3				
RT Plan Storage	1.2.840.10008.5.1.4.1.1.481.5				

4.2.2.3.1.3 SOP Specific Conformance for All SOP Classes

TomoUser provides Level 0 Conformance as an SCU. The following table describes processing of status codes received from a Storage SCP.

Table 16. Warning and Error Statuses

Status Code	Meaning	TomoUser Response
-------------	---------	-------------------

Status Code	Meaning	TomoUser Response
0106	Error: invalid attribute	Association released. Error reported.
0107	Warning: bad attribute	Association released. Error reported.
0110	Processing failure	Association released. Error reported.
0111	Duplicate instance	Association released. Error reported.
0112	Error: no object instance	Association released. Error reported.
0115	Error: invalid argument	Association released. Error reported.
0116	Warning: value out of range	Association released. Error reported.
0118	Error: no such SOP class	Association released. Error reported.
0119	Error: class instance conflict	Association released. Error reported.
0120	Error: missing attribute	Association released. Error reported.
0122	Error: SOP unsupported	Association released. Error reported.
0210	Error: duplicate request	Association released. Error reported.
0211	Error: unrecognized operation	Association released. Error reported.
0213	Error: resource limitation	Association released. Error reported.
A700	Refused: out of resources	Association released. Error reported.
A900	Error: data set mismatch	Association released. Error reported.
B000	Warning: data element coercion	Association released. Error reported.
B006	Warning: elements discarded	Association released. Error reported.
B007	Warning: data set mismatch	Association released. Error reported.
C001 and all others	Error: cannot understand	Association released. Error reported.

4.2.2.3.1.4 SOP Specific Conformance for Verification Class

TomoUser provides standard conformance to the DICOM Verification Class as a Service Class User.

4.3 Network Interfaces

4.3.1 Physical Network Interface

TomoProvider and TomoUser are indifferent to the physical medium over which TCP/IP executes. This behavior is inherited from the Windows 2000 or Windows XP system upon which they reside. In TomoTherapy applications the physical medium will be 100BaseT or faster.

4.3.2 Additional Protocols

No additional protocols.

4.4 Configuration

4.4.1 AE Title/Presentation Address Mapping

4.4.1.1 Local AE Titles

The default AE Title for the SCP Application Entity is TomoProvider.

The AE Title for the SCU Application Entity is TomoUser. The AE Title is not configurable.

Table 17. AE Title Configuration Table

Application Entity	Default AE Title	Default TCP/IP Port
Storage SCP	TomoProvider	104
Storage SCU	TomoUser	Not applicable

The `Dicom.properties` file in the `$CONFIG` directory provides address mapping information. A mapping is permitted between the TomoProvider, its AE Title, and its port. At installation, these are defined in the `Dicom.properties` file specified above as:

```
ProviderAETitle = TomoProvider
```

```
Port = "104"
```

They may be changed as required by site needs.

4.4.1.2 Remote AE Title/Presentation Address Mapping

Configuration of DICOM remote AE destinations is made using the “DICOM Destination Maintenance Utility” in the “DICOM options...” selection of the TomoTherapy application tools menu. This option is available on both the TomoTherapy Hi-ART Operator Station (installed outside the treatment bunker) and on the TomoTherapy Hi-ART Planning Station (typically located in the treatment planning room). Privileged access may be required to select this option.

Users with appropriate permissions may configure the following fields for every remote DICOM Application Entity with which the TomoUser communicates:

- Name used for selection (a descriptive name for the export destination you are creating or editing)
- Application Entity Title (the AE title for the export destination you are creating or editing). This information is available from the DICOM Conformance Statement of the remote equipment.
- Machine name or IP Address (the network location for the export destination you are creating or editing)
- IP port (the IP Port used by the export destination you are creating or editing). This information is available from the DICOM Conformance Statement of the remote equipment.
- Connection timeout (seconds) (the length of time the TomoTherapy export service will attempt to connect to the remote destination). Range 0-300 seconds, default 30 seconds.
- Maximum packet size (the maximum data size of each data packet that the Hi-ART System will export). Default 8k; most treatment planning systems accept 8k or 32k – this information is available from the DICOM Conformance Statement of the remote equipment.

Options are available in the user interface to add, delete or change these configuration parameters.

Note: For diagnostic purposes, the last transmitted object of a transmitted series is always stored in DICOM Part 10 format. Its default location is defined in `LogFile.properties`. The file name is `dicom.out`.

Note: Logs of the activities of the TomoProvider server are kept in file `TomoLog_EDI.tlg` in directory `c:\tomo\logs`.

Note: Logs of the activities of the TomoUser server are kept in file `TomoLog_EXP.tlg` in directory `c:\tomo\logs`.

4.4.2 Parameters

Table 18. Configuration Parameters Table

Parameter	Configurable (Yes/No)	Default Value
General		
DebugPath (path for location of debugging files)	Yes	c:/tomo/logs (configurable in \$CONFIG/Dicom.properties)
DebugLevel (level of debugging information generated): -1 = no debugging info generated 0 = DICOM debug file generated	Yes	-1 (configurable in \$CONFIG/Dicom.properties)

Parameter	Configurable (Yes/No)	Default Value
SCP (TomoProvider)		
SCP Local AE Title	Yes	TomoProvider (configurable in \$CONFIG/Dicom.properties)
Port (SCP listening port)	Yes	104 (configurable in \$CONFIG/Dicom.properties)
SCP Maximum PDU Size sent	No	8192
SCP Maximum PDU Size received	No	No limit
SCP Number of Associations	No	No limit
VerticalDeviation: The maximum tolerated variation (in cm) in vertical image position across the slices of an imported CT data set, as defined in the attribute Image Position (Patient) (0020,0032).	Yes	0.01
Socket Timeout: The SCP Remote Connection Timeout.	Yes	60 (configurable in \$CONFIG/Dicom.properties)
SCU (TomoUser)		
SCU Maximum PDU Size received	No	No limit
SCU Maximum PDU Size sent	Yes	8192 (configurable from DICOM Destination Maintenance Utility)
SCU Remote AE Title	Yes	No default (configurable from DICOM Destination Maintenance Utility)
SCU Remote IP address/machine name	Yes	No default (configurable from DICOM Destination Maintenance Utility)
SCU Remote IP Port	Yes	104 (configurable from DICOM Destination Maintenance Utility)
SCU Remote Connection Timeout	Yes	30 seconds (configurable from DICOM Destination Maintenance Utility)

5 Media Interchange

TomoTherapy applications do not support DICOM Media Interchange.

6 Support of Character Sets

TomoProvider and TomoUser support only SOP Instances containing the DICOM default character set (ISO 646) as defined in PS 3.5 (see also PS 3.3, Section C.12.1.1.2).

7 Security

TomoTherapy applications do not support DICOM Security Profiles.

8 Annexes

8.1 IOD Contents

8.1.1 Created SOP Instances

Table 19. Abbreviations Used for Presence of Values

Abbreviation	Meaning
VNAP	Value Not Always Present (attribute sent zero length if no value is present)
ANAP	Attribute Not Always Present
ALWAYS	Always present with a value
EMPTY	Attribute is sent without a value
ABSENT	Attribute never present

Note: All attributes are generated automatically.

8.1.1.1 Common Modules

The following tables outline attribute mappings for modules where those mappings are common to two or more supported storage IODs.

Table 20. Patient Module

Attribute Name	Element Tag	Type	Usage notes
Patient's Name	(0010,0010)	2	ALWAYS: The selected patient's name
Patient ID	(0010,0020)	2	ALWAYS: The selected patient's MRN (medical record number)
Patient's Birth Date	(0010,0030)	2	VNAP: The selected patient's birth date
Patient's Sex	(0010,0040)	2	VNAP: For the selected patient: 'M' if Male, 'F' if Female, 'O' if Other, not valued if unknown
Patient's Birth Time	(0010,0032)	3	ANAP: The selected patient's time of birth
Other Patient IDs	(0010,1000)	3	ANAP: The selected patient's other IDs
Other Patient Names	(0010,1001)	3	ANAP: The selected patient's other names
Ethnic Group	(0010,2160)	3	ANAP: The selected patient's ethnic group
Patient Comments	(0010,4000)	3	ANAP: Patient comments

			that may be associated with the patient record
--	--	--	--

Table 21. General Study Module

Attribute Name	Element Tag	Type	Usage notes
Study Instance UID	(0020,000D)	1	ALWAYS: The TomoTherapy UID for the disease containing the image
Study Date	(0008,0020)	2	ALWAYS: The date of creation for the disease
Study Time	(0008,0030)	2	ALWAYS: The time of creation for the disease
Referring Physician's Name	(0008,0090)	2	EMPTY
Study ID	(0020,0010)	2	ALWAYS: TomoTherapy Disease Name
Accession Number	(0008,0050)	2	EMPTY
Study Description	(0008,1030)	3	ALWAYS: Value 'TomoTherapy Patient Disease'
Physician(s) of Record	(0008,1048)	3	ANAP: The attending oncologist associated with the disease
No other fields sent from the General Study Module			

Table 22. Patient Study Module

Attribute Name	Element Tag	Type	Usage notes
Admitting Diagnoses Description	(0008,1080)	3	ANAP: The admitting diagnoses description for the disease
Patient's Age	(0010,1010)	3	ANAP: The patient's age as kept in the disease
Patient's Size	(0010,1020)	3	ANAP: The patient's height in cm from the disease, converted to meters. Not sent if height is zero.
Patient's Weight	(0010,1030)	3	ANAP: The patient's weight in kg from the disease. Not sent if weight is zero.
Additional Patient's History	(0010,21B0)	3	ANAP: Additional patient's history as kept in the disease record

Table 23. General Equipment Module

Attribute Name	Element Tag	Type	Usage notes
Manufacturer	(0008,0070)	2	VNAP: Manufacturer of equipment that created object. Value 'TomoTherapy Incorporated' for all objects exported by TomoTherapy.
Institution Name	(0008,0080)	3	ANAP: Name of institution that created object. Institution where TomoTherapy equipment is installed for all objects created by TomoTherapy.
Station Name	(0008,1010)	3	ANAP: The name of the Hi-ART System ('machine name') that created object. Present for RT Doses and RT Plans. Present for TomoImages, absent for exported kVCT images. Absent for RT Structure Sets.
Manufacturer's Model Name	(0008,1090)	3	ANAP: The machine model type associated with the equipment that created object. Value 'Hi-Art' for all objects created by TomoTherapy.
Device Serial Number	(0018,1000)	3	ANAP: The device serial number associated with the equipment that created object. Value of Hi-ART serial number (if available in database). See Station Name for objects that may supply this attribute.
Software Versions	(0018,1020)	3	ANAP: The device software versions associated with the equipment that created object. Value of Hi-ART software version for all objects created by TomoTherapy. Multiplicity is always 1.
Pixel Padding Value	(0028,0120)	3	ALWAYS: Value = 0
No other fields sent from the General Equipment Module			

8.1.1.2 CT Image Storage Class

The following tables identify the entities for each IOD module for a CT Image Store Request operation. The table indicates which IOD Entities have fields that will be retrieved from the TomoTherapy Data Server to construct the object(s) for the C-STORE operation.

Note that all type 3 fields are populated if the field value is non-blank. If it is blank, it will not be sent.

Table 24. CT Image IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 20
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 21
	Patient Study	U	Table 22
	Clinical Trial Study	U	Not used
Series	General Series	M	Table 25
	Clinical Trial Series	U	Not used
Frame of Reference	Frame of Reference	M	Table 26
Equipment	General Equipment	M	Table 23
Image	General Image	M	Table 27
	Image Plane	M	Table 28
	Image Pixel	M	Table 29
	Contrast/bolus	C	Not used
	CT Image	M	Table 30
	Overlay Plane	U	Not used
	VOI LUT	U	Not used
	SOP Common	M	Table 31

Table 25. General Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	ALWAYS: Value 'CT'
Series Instance UID	(0020,000E)	1	ALWAYS: The TomoTherapy UID from the image set database object being transmitted
Series Number	(0020,0011)	2	ALWAYS: Value equal to the Series Date month and day values (with any leading zero removed), concatenated with the Series Time hour, minute, and whole-number second portions, e.g. '1231235959'.

Attribute Name	Element Tag	Type	Usage notes
Series Date	(0008,0021)	3	ALWAYS: The date the image was created in the TomoTherapy database
Series Time	(0008,0031)	3	ALWAYS: The time the image was created in the TomoTherapy database
Series Description	(0008,103E)	3	ALWAYS: Value 'kVCT Image Set' for kV images, 'TomolImage Set' for TomolImages.
Patient Position	(0018,5100)	2C	ALWAYS: The patient position for the image being transmitted: Value one of 'HFS', 'FFS', 'HFP', or 'FFP'.
No other fields sent from the General Series Module			

Table 26. Frame of Reference Module

Attribute Name	Element Tag	Type	Usage notes
Frame of Reference UID	(0020,0052)	1	ALWAYS: For planning data sets, equal to the original Frame of Reference UID from the images transmitted to TomoTherapy. For TomolImage data sets, equal to the TomoTherapy UID from the image set being transmitted suffixed with '.1.1'.
Position Reference Indicator	(0020,1040)	2	EMPTY
No other fields sent from the Frame of Reference Module			

Table 27. General Image Module

Attribute Name	Element Tag	Type	Usage notes
Instance Number	(0020,0013)	2	ALWAYS: TomoTherapy Image slice number for this slice, starting at 1.
Image Type	(0008,0008)	1	See CT Image Module
Acquisition Date	(0008,0022)	3	ALWAYS: Creation date of the image
Acquisition Time	(0008,0032)	3	ALWAYS: Creation time of the image
Derivation Description	(0008,2111)	3	ANAP: For resampled kVCT image sets, value "Resampled kVCT data set".

Attribute Name	Element Tag	Type	Usage notes
			Absent for all other objects.
Images in Acquisition	(0020,1002)	3	ALWAYS: Total number of slices in the image series
No other fields sent from the General Image Module			

Table 28. Image Plane Module

Attribute Name	Element Tag	Type	Usage notes
Pixel Spacing	(0028,0030)	1	ALWAYS: The pixel-to-pixel spacing from the CT image in cm converted to mm. X and Y dimensions are provided.
Slice Thickness	(0018,0050)	2	ALWAYS: The slice thickness from the CT image in cm, converted to mm
Image Orientation (Patient)	(0020,0037)	1	ALWAYS: 1) -1.0 (FFS, HFP) or 1.0 (HFS, FFP) 2) 0.0 3) 0.0 4) 0.0 5) -1.0 (HFP, FFP) or 1.0 (HFS, FFS) 6) 0.0
Image Position (Patient)	(0020,0032)	1	ALWAYS: The coordinates in patient space for the first pixel sent in the array data, converted to mm
Slice Location	(0020,1041)	3	ALWAYS: The longitudinal location of the slice in TomoTherapy machine coordinates, converted to mm. This is equivalent to the position along the IEC Yt or Yf axis, but where the location origin coincides with the origin of the DICOM Patient Coordinate System. Note that slice location is of opposite sign to the contour z (DICOM) coordinates for HFS and HFP patients.
No other fields sent from the Image Plane Module			

Table 29. Image Pixel Module

Attribute Name	Element Tag	Type	Usage notes
Samples per Pixel	(0028,0002)	1	See CT Image Module
Photometric Interpretation	(0028,0004)	1	See CT Image Module
Rows	(0028,0010)	1	ALWAYS: The number of rows in the image
Columns	(0028,0011)	1	ALWAYS: The number of columns in the image
Bits Allocated	(0028,0100)	1	See CT Image Module
Bits Stored	(0028,0101)	1	See CT Image Module
High Bit	(0028,0102)	1	See CT Image Module
Pixel Representation	(0028,0103)	1	ALWAYS: Value 0 (unsigned data)
Pixel Data	(7FE0,0010)	1	ALWAYS: The 16-bit array data for the given slice
Smallest Image Pixel Value	(0028,0106)	3	ALWAYS: Value 0
No other fields sent from the Image Pixel Module. Duplicate field definitions in the CT Image Module are described in the CT Image Module.			

Table 30. CT Image Module

Attribute Name	Element Tag	Type	Usage notes
Image Type	(0008,0008)	1	ALWAYS: 1 st value: 'ORIGINAL' 2 nd value: 'PRIMARY' if TomoImage, 'SECONDARY' otherwise 3 rd value: 'AXIAL'
Samples per Pixel	(0028,0002)	1	ALWAYS: Value 1
Photometric Interpretation	(0028,0004)	1	ALWAYS: Value 'MONOCHROME2'
Bits Allocated	(0028,0100)	1	ALWAYS: Value 16
Bits Stored	(0028,0101)	1	ALWAYS: Value 16
High Bit	(0028,0102)	1	ALWAYS: Value 15
Rescale Intercept	(0028,1052)	1	ALWAYS: Value -1024
Rescale Slope	(0028,1053)	1	ALWAYS: Value 1.0
KVP	(0018,0060)	2	VNAP: Value 6000.0 for TomoImage data, or not valued (EMPTY) for kVCT images
Acquisition Number	(0020, 0012)	2	EMPTY.
No other fields sent from the CT Image Module. Duplicate field definitions from the Image Pixel Module are described in this module.			

Table 31. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	ALWAYS: Value = '1.2.840.10008.5.1.4.1.1.2'
SOP Instance UID	(0008,0018)	1	ALWAYS: The TomoTherapy UID from the image set database object being transmitted suffixed with ':' and the slice number.
Specific Character Set	(0008,0005)	1C	ABSENT. TomoTherapy does not currently support extended or replacement character sets.
Instance Creation Date	(0008,0012)	3	ALWAYS: Date of actual object construction (object send time)
Instance Creation Time	(0008,0013)	3	ALWAYS: Time of actual object construction (object send time)
No other fields sent from the SOP Common Module			

8.1.1.3 RT Dose Storage Class

The following tables identify the entities for each IOD module for a RT Dose Store Request operation. The table indicates which IOD Entities have fields that will be retrieved from the TomoTherapy Data Server to construct the object(s) for the C-STORE operation.

Note that all type 3 fields are populated if the field value is non-blank. If it is blank, it will not be sent.

Table 32. RT Dose IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 20
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 21
	Patient Study	U	Table 22
	Clinical Trial Study	U	Not used
Series	RT Series	M	Table 33
	Clinical Trial Series	U	Not used
Frame of Reference	Frame of Reference	M	Table 34
Equipment	General Equipment	M	Table 23
Dose	General Image	C	Table 35
	Image Plane	C	Table 36
	Image Pixel	C	Table 37
	Multi-Frame	C	Table 38
	Overlay Plane	U	Not used
	Multi-Frame Overlay	U	Not used
	Modality LUT	U	Not used
	RT Dose	M	Table 39
	RT DVH	U	Table 40 (absent for Tomo QA plan doses)
	Structure Set	C	Not used
	ROI Contour	C	Not used
	RT Dose ROI	C	Not used
	Audio	U	Not used
SOP Common	M	Table 41	

Table 33. RT Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	ALWAYS: Value 'RTDOSE'
Series Instance UID	(0020,000E)	1	ALWAYS: The

Attribute Name	Element Tag	Type	Usage notes
			TomoTherapy UID from the dose image being transmitted, suffixed with '.1'
Series Number	(0020,0011)	2	ALWAYS: Value equal to the month and day values of the database creation date (with any leading zero removed), concatenated with the hour, minute, and whole-number second values of the database creation time, e.g. '1231235959'.
Series Description	(0008,103E)	3	ALWAYS: Value one of 'TomoTherapy Planned Dose', 'TomoTherapy Reconstructed Dose', 'TomoTherapy Cumulative Dose', or 'TomoTherapy Delivery QA Dose'. Some of these types may not be supported by the current Hi-Art release.
No other fields sent from the RT Series Module			

Table 34. Frame of Reference Module

Attribute Name	Element Tag	Type	Usage notes
Frame of Reference UID	(0020,0052)	1	ALWAYS: For plan-based doses, value is the same Frame of Reference UID (0020,0052) as that found in the CT data set upon which the structure set used to calculate the RT Dose object is based. For fraction-based doses, value is the TomoTherapy image set UID suffixed with ".1.1".
Position Reference Indicator	(0020,1040)	2	EMPTY
No other fields sent from the Frame of Reference Module			

Table 35. General Image Module

Attribute Name	Element Tag	Type	Usage notes
Instance Number	(0020,0013)	2	See RT Dose Module
Image Type	(0008,0008)	3	ALWAYS: 1 st value: ORIGINAL

Attribute Name	Element Tag	Type	Usage notes
			2 nd value: PRIMARY 3 rd value: AXIAL
Acquisition Date	(0008,0022)	3	ALWAYS: Creation date of the image
Acquisition Time	(0008,0032)	3	ALWAYS: Creation time of the image
Referenced Image Sequence	(0008,1140)	3	ALWAYS: This sequence references the CT image set upon which the plan referenced by this dose is based. Number of items = number of slices in CT image set. See Table 44 Note 1.
>Referenced SOP Class UID	(0008,1150)	1	ALWAYS: Value = '1.2.840.10008.5.1.4.1.1.2'
>Referenced SOP Instance UID	(0008,1160)	1	ALWAYS: The TomoTherapy UID from the CT image set database object, suffixed with '.' and the slice number.
Images in Acquisition	(0020,1002)	3	ALWAYS: Value 1
No other fields sent from the General Image Module			

Table 36. Image Plane Module

Attribute Name	Element Tag	Type	Usage notes
Pixel Spacing	(0028,0030)	1	ALWAYS: The pixel-to-pixel spacing from the dose image in cm converted to mm. X and Y dimensions are provided.
Image Orientation (Patient)	(0020,0037)	1	ALWAYS: Values: 1) -1.0 (FFS, HFP) or 1.0 (HFS, FFP) 2) 0.0 3) 0.0 4) 0.0 5) -1.0 (HFP, FFP) or 1.0 (HFS, FFS) 6) 0.0

Attribute Name	Element Tag	Type	Usage notes
Image Position (Patient)	(0020,0032)	1	ALWAYS: The coordinates in patient space for the first pixel sent in the array data, converted to mm. This pixel lies in the first pixel plane transmitted. This pixel plane will be in the same location as the first slice of the underlying CT data referenced in the Referenced Image Sequence (0008,1140).
Slice Thickness	(0018,0050)	2	ALWAYS: The slice thickness from the dose image in cm converted to mm
Slice Location	(0020,1041)	3	ALWAYS: The longitudinal location of the first slice sent in TomoTherapy machine coordinates, converted to mm. This is equivalent to the position along the IEC Yt or Yf axis, but where the location origin coincides with the origin of the DICOM Patient Coordinate System. Note that slice location is of opposite sign to the contour z (DICOM) coordinates for HFS and HFP patients.
No other fields sent from the Image Plane Module			

Table 37. Image Pixel Module

Attribute Name	Element Tag	Type	Usage notes
Samples per Pixel	(0028,0002)	1	See RT Dose Module
Photometric Interpretation	(0028,0004)	1	See RT Dose Module
Rows	(0028,0010)	1	ALWAYS: The number of rows in the image
Columns	(0028,0011)	1	ALWAYS: The number of columns in the image
Bits Allocated	(0028,0100)	1	See RT Dose Module
Bits Stored	(0028,0101)	1	See RT Dose Module
High Bit	(0028,0102)	1	See RT Dose Module
Pixel Representation	(0028,0103)	1	See RT Dose Module
Pixel Data	(7FE0,0010)	1	ALWAYS: The array data for the 3D dose array. This data will contain the same number of pixels as the entire series of underlying

Attribute Name	Element Tag	Type	Usage notes
			CT data referenced in the Referenced Image Sequence (0008,1140).
Smallest Image Pixel Value	(0028,0106)	3	ALWAYS: Value 0
No other fields sent from the Image Pixel Module			

Table 38. Multi-Frame Module

Attribute Name	Element Tag	Type	Usage notes
Number of Frames	(0028,0008)	1	ALWAYS: The number of axial slices in the 3D dose grid. This will equal the number of CT images referenced in the Referenced Image Sequence (0008,1140).
Frame Increment Pointer	(0028,0009)	1	ALWAYS: Value (3004,000C) (Grid Frame Offset Vector).

Table 39. RT Dose Module

Attribute Name	Element Tag	Type	Usage notes
Samples per Pixel	(0028,0002)	1C	ALWAYS: Value 1
Photometric Interpretation	(0028,0004)	1C	ALWAYS: Value 'MONOCHROME2'
Bits Allocated	(0028,0100)	1C	ALWAYS: Value 16
Bits Stored	(0028,0101)	1C	ALWAYS: Value 16
High Bit	(0028,0102)	1C	ALWAYS: Value 15
Pixel Representation	(0028,0103)	1C	ALWAYS: Value 0 (unsigned data)
Dose Units	(3004,0002)	1	ALWAYS: Value 'GY'
Dose Type	(3004,0004)	1	ALWAYS: Value 'PHYSICAL'
Instance Number	(0020,0013)	3	ALWAYS: Value 2
Dose Comment	(3004,0006)	3	ALWAYS: Plan Label of referenced plan object in TomoTherapy database.
Dose Summation Type	(3004,000A)	1	ALWAYS: Value 'PLAN' for planned and delivery QA doses, 'FRACTION' for reconstructed and cumulative doses.
Referenced RT Plan Sequence	(300C,0002)	1C	ALWAYS: Number of items = 1

Attribute Name	Element Tag	Type	Usage notes
>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.5'
>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS: TomoTherapy UID of referenced plan object in TomoTherapy database.
>Referenced Fraction Group Sequence	(300C,0020)	1C	ALWAYS if Dose Summation Type is 'FRACTION'. Number of items = 1. ABSENT otherwise.
>>Referenced Fraction Group Number	(300C,0022)	1C	ALWAYS: Value 1
Grid Frame Offset Vector	(3004,000C)	1C	ALWAYS: An array of values equal in size to the number of axial slices transmitted in the dose image. First array value = 0.0 (1 st slice), second array value = location of 2 nd slice relative to 1 st slice (in mm), third array value = location of 3 rd slice relative to 1 st slice (in mm), and so on. Note that the coordinates are in the DICOM Patient-based (LPS) coordinate system, so offsets may be negative for some patient orientations.
Dose Grid Scaling	(3004,000E)	1	ALWAYS: Multiplier to be applied to dose grid data in Pixel Data to yield values in GY.
Tissue Heterogeneity Correction	(3004,0014)	3	ALWAYS: Value 'ROI_OVERRIDE' (indicates dose calculation calculated taking into account tissue heterogeneity, with density overriding pixel values if present).
No other fields sent from the RT Dose Module			

Table 40. RT DVH Module

Attribute Name	Element Tag	Type	Usage notes
Referenced Structure Set Sequence	(300C,0060)	1	ALWAYS: Number of items = 1
>Referenced SOP Class UID	(0008,1150)	1	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.3'

Attribute Name	Element Tag	Type	Usage notes
>Referenced SOP Instance UID	(0008,1155)	1	ALWAYS: SOP Instance UID of RT Structure Set upon which dose is based (i.e. the structure set associated with the plan for which the dose is calculated).
DVH Sequence	(3004,0050)	1	ALWAYS: Number of items = number of ROIs in related structure set that have non-zero DVH data
>DVH Referenced ROI Sequence	(3004,0060)	1	ALWAYS: Number of items = 1
>>Referenced ROI Number	(3006,0084)	1	ALWAYS: ROI Number of ROI in referenced structure set
>>DVH ROI Contribution Type	(3004,0062)	1	ALWAYS: Value 'INCLUDED'. Portions of other ROIs located within the contour of the current ROI are included in DVH information for the current ROI.
>DVH Type	(3004,0001)	1	ALWAYS: Value 'DIFFERENTIAL'
>Dose Units	(3004,0002)	1	ALWAYS: Value 'GY'
>Dose Type	(3004,0004)	1	ALWAYS: Value 'PHYSICAL'
>DVH Dose Scaling	(3004,0052)	1	ALWAYS: Value 1.0
>DVH Volume Units	(3004,0054)	1	ALWAYS: Value 'CM3'
>DVH Number of Bins	(3004,0056)	1	ALWAYS: Number of bins for DVH curve for current ROI. For DVH curves stored in the database with a non-zero start bin index, the number of bins will be one more than the number of bins in the database, with a 'wide' zero-dose bin added at the start of the sequence.
>DVH Data	(3004,0058)	1	ALWAYS: Differential DVH width/volume pairs D_n, V_n . Typically there are several hundred data points for each DVH curve.
No other fields sent from the RT DVH Module			

Table 41. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.2'
SOP Instance UID	(0008,0018)	1	ALWAYS: The TomoTherapy UID from the dose image being transmitted
Specific Character Set	(0008,0005)	1C	ABSENT. TomoTherapy does not currently support expanded or replacement character sets.
Instance Creation Date	(0008,0012)	3	ALWAYS: Date of actual object construction (object send time)
Instance Creation Time	(0008,0013)	3	ALWAYS: Time of actual object construction (object send time)
No other fields sent from the SOP Common Module			

8.1.1.4 RT Structure Set Storage Class

The following tables identify the entities for each IOD module for a RT Structure Set Store Request operation. The table indicates which IOD Entities have fields that will be retrieved from the TomoTherapy Data Server to construct the object(s) for the C-STORE operation.

Note that all type 3 fields are populated if the field value is non-blank. If it is blank, it will not be sent.

Table 42. RT Structure Set IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 20
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 21
	Patient Study	U	Not used
	Clinical Trial Study	U	Not used
Series	RT Series	M	Table 43
	Clinical Trial Series	U	Not used
Equipment	General Equipment	M	Not used
Structure Set	Structure Set	M	Table 44
	ROI Contour	M	Table 45
	RT ROI Observations	M	Table 46
	Approval	U	Not used
	Audio	U	Not used
	SOP Common	M	Table 47

Table 43. RT Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	ALWAYS: Value 'RTSTRUCT'
Series Instance UID	(0020,000E)	1	ALWAYS: The TomoTherapy UID from the structure set being transmitted, suffixed with '.1'
Series Number	(0020,0011)	2	ALWAYS: Value equal to the month and day values of the database creation date (with any leading zero removed), concatenated with the hour, minute, and whole-number second values of the database creation time, e.g. '1231235959', plus 1 (to differentiate between RT Plan created at same

Attribute Name	Element Tag	Type	Usage notes
			instant).
Series Description	(0008,103E)	3	ALWAYS: Value 'TomoTherapy Structure Set'
No other fields sent from the RT Series Module			

Table 44. Structure Set Module

Attribute Name	Element Tag	Type	Usage notes
Structure Set Label	(3006,0002)	1	ALWAYS: For disease-level structure sets, the Structure Set Label from the originally imported Structure Set. For plan-level structure sets, the Plan Label for the associated RT Plan (e.g. 'Plan_01').
Structure Set Name	(3006,0004)	3	Disease-level structure sets: ANAP: the Structure Set Name from the originally imported Structure Set, if present. Plan-level structure sets: ALWAYS: The Plan Label for the associated RT Plan (e.g. 'Plan_01').
Structure Set Description	(3006,0006)	3	Disease-level structure sets: ABSENT. Plan-level structure sets: ALWAYS: The Plan Label for the associated RT Plan (e.g. 'Plan_01').
Instance Number	(0020,0013)	3	ALWAYS: Value 3
Structure Set Date	(3006,0008)	2	ALWAYS: Date at which structure set was last modified
Structure Set Time	(3006,0009)	2	ALWAYS: Time at which structure set was last modified
Referenced Frame of Reference Sequence	(3006,0010)	3	ALWAYS: Number of items = 1
> Frame of Reference UID	(0020,0052)	1C	ALWAYS: Equal to Frame of Reference UID in CT Image Series referenced by this structure set.
>RT Referenced Study Sequence	(3006,0012)	3	ALWAYS: Number of items = 1

Attribute Name	Element Tag	Type	Usage notes
>>Referenced SOP Class UID	(0008,1150)	1	ALWAYS: Value '1.2.840.10008.3.1.2.3.1' (Detached Study Management SOP Class)
>>Referenced SOP Instance UID	(0008,1155)	1	ALWAYS: Study Instance UID of CT data set upon which structure set is based, also corresponding to TomoTherapy UID of disease in TomoTherapy database
>>RT Referenced Series Sequence	(3006,0014)	1C	ALWAYS: Number of items = 1. See Note 1.
>>>Series Instance UID	(0020,000E)	1C	ALWAYS: Series Instance UID of CT data set upon which structure set is based, also corresponding to TomoTherapy UID of associated image CT data set in TomoTherapy database.
>>>Contour Image Sequence	(3006,0016)	1C	ALWAYS: Number of items = number of axial images (slices) in CT data set upon which structure set is based.
>>>>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.2' (CT Image Storage SOP Class)
>>>>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS: SOP Instance UID of one of the images upon which structure set is based, also corresponding to TomoTherapy UID of CT data set in TomoTherapy database suffixed with '.' followed by the image number. All series images will be referenced here (even if one or more images contains no contours).
Structure Set ROI Sequence	(3006,0020)	3	ALWAYS: Number of items = number of ROIs in TomoTherapy structure set, including any points of interest (POIs) defined on the TomoTherapy System.
>ROI Number	(3006,0022)	1C	ALWAYS: Sequential index starting at 1, with ROIs listed first, then POIs. These indices are not necessarily

Attribute Name	Element Tag	Type	Usage notes
			the same as the TomoTherapy ROI (structure) number.
>Referenced Frame of Reference UID	(3006,0024)	1C	ALWAYS: Value encoded in Frame of Reference UID (0020,0052) in unique item of Referenced Frame of Reference Sequence in this module.
>ROI Name	(3006,0026)	2C	ALWAYS: TomoTherapy ROI name for regions or POI name for points
>ROI Generation Algorithm	(3006,0036)	2C	ALWAYS: Value = 'MANUAL'
No other fields sent from the Structure Set Module			

Note 1: After TomoTherapy has received them, kVCT image sets may be modified for planning purposes, in particular for couch removal and density override. TomoTherapy RT Structure Set and RT Dose objects reference an image set according to the following rules:

- If an image containing one or more density overrides (a 'final modified associated image') is present, TomoTherapy references that image set, otherwise
- If a couch removal image (a 'modified associated image') is present, TomoTherapy references that image set, otherwise
- TomoTherapy references the image set originally generated by resampling the imported diagnostic image set (an 'associated image').

When exporting RT Structure Set data, it is important to ensure that the correct kVCT image set is selected in the export dialog, so that the RT Structure Set UID link will reference an existing image set when processed by the receiving application.

Table 45. ROI Contour Module

Attribute Name	Element Tag	Type	Usage notes
ROI Contour Sequence	(3006,0039)	1	ALWAYS: Number of items = sum of number of regions and number of points in TomoTherapy structure set
>Referenced ROI Number	(3006,0084)	1	ALWAYS: Corresponding ROI Number in Structure Set Module.
>ROI Display Color	(3006,002A)	3	ALWAYS: RGB representation of color assigned to region or point

Attribute Name	Element Tag	Type	Usage notes
>Contour Sequence	(3006,0040)	3	ALWAYS: Number of items = number of contours in region, or one (1) for points
>>Contour Image Sequence	(3006,0016)	3	ANAP: Always present with number of items = 1 for regions. Present with number of items = 1 for a point if it lies on a slice, otherwise absent.
>>>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS (if sequence present): Value '1.2.840.10008.5.1.4.1.1.2' (CT Image Storage SOP Class)
>>>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS (if sequence present): SOP Instance UID of the image upon which contour is based, also corresponding to TomoTherapy UID of CT data set in TomoTherapy database suffixed with '.' followed by the image number.
>>Contour Geometric Type	(3006,0042)	1C	ALWAYS: Value 'CLOSED_PLANAR' (for regions) or 'POINT' (for points)
>>Contour Slab Thickness	(3006,0044)	3	ANAP: For regions, value equal to inter-slice spacing of CT data set. Attribute absent for points.
>>Contour Offset Vector	(3006,0045)	3	ANAP: For regions, value (0.0, 0.0, 0.0). Attribute absent for points.
>>Number of Contour Points	(3006,0046)	3	ALWAYS: Number of points (triplets) in contour data. Always 1 for points.
>>Contour Data	(3006,0050)	1C	ALWAYS: Sequence of (x,y,z) triplets defining contour or point in patient-based coordinate system
No other fields sent from the ROI Contour Module			

Table 46. RT ROI Observations Module

Attribute Name	Element Tag	Type	Usage notes
RT ROI Observations Sequence	(3006,0080)	1	ALWAYS: Number of items = sum number of regions and number of points in TomoTherapy structure set
>Observation Number	(3006,0082)	1	ALWAYS: Corresponding ROI Number in Structure Set Module.
>Referenced ROI Number	(3006,0084)	1	ALWAYS: Corresponding ROI Number in Structure Set Module.
>RT ROI Interpreted Type	(3006,00A4)	2	<p>VNAP: ROIs: Original RT ROI Interpreted Type of imported ROIs. An ROI with a name equal to "couch" (case-insensitive) will be assigned an RT ROI Interpreted Type of 'SUPPORT'.</p> <p>Points: A point will be assigned a value of 'MARKER' for fiducial points, 'ISOCENTER' if the ROI Name (3006,0026) contains the string 'isocenter' or 'isocenter' (ignoring case), or 'DOSE_REGION' otherwise.</p> <p>If the interpreted type for the ROI or point is not known, an observation will still be included with this attribute not valued (EMPTY).</p>
>ROI Interpreter	(3006,00A6)	2	EMPTY
>ROI Physical Properties Sequence	(3006,00B0)	3	ANAP: Sequence will be present if ROI is a region and has a density override
>>ROI Physical Property	(3006,00B2)	1C	ANAP: Present if ROI is a region and has a density override, Value 'REL_ELEC_DENSITY'.
>>ROI Physical Property Value	(3006,00B4)	1C	ANAP: Present if ROI is a region and has a density override. Value equal to assigned relative electron density.
No other fields sent from the RT ROI Observations Module			

Table 47. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.3'
SOP Instance UID	(0008,0018)	1	ALWAYS: The TomoTherapy UID from the structure set being transmitted
Specific Character Set	(0008,0005)	1C	ABSENT. TomoTherapy does not currently support expanded or replacement character sets.
Instance Creation Date	(0008,0012)	3	ALWAYS: Date of actual object construction (object send time)
Instance Creation Time	(0008,0013)	3	ALWAYS: Time of actual object construction (object send time)
No other fields sent from the SOP Common Module			

8.1.1.5 RT Plan Storage Class

The following tables identify the entities for each IOD module for a RT Plan Store Request operation. The table indicates which IOD Entities have fields that will be retrieved from the TomoTherapy Data Server to construct the object(s) for the C-STORE operation.

Note that all type 3 fields are populated if the field value is non-blank. If it is blank, it will not be sent.

Table 48. RT Plan IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 20
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 21
	Patient Study	U	Not used
	Clinical Trial Study	U	Not used
Series	RT Series	M	Table 49
	Clinical Trial Series	U	Not used
Frame of Reference	Frame of Reference	U	Table 50
Equipment	General Equipment	M	Not used
Plan	RT General Plan	M	Table 51
	RT Prescription	U	Table 52 (absent for Tomo QA plans)
	RT Tolerance Tables	U	Not used
	RT Patient Setup	U	Table 54
	RT Fraction Scheme	U	Table 55
	RT Beams	C	Table 56
	RT Brachy Application Setups	C	Not used
	Approval	U	Table 57
	Audio	U	Not used
	SOP Common	M	Table 58

Table 49. RT Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	ALWAYS: Value 'RTPLAN'
Series Instance UID	(0020,000E)	1	ALWAYS: The TomoTherapy UID from the plan being transmitted, suffixed with '.1'
Series Number	(0020,0011)	2	ALWAYS: Value equal to the month and day values of the

Attribute Name	Element Tag	Type	Usage notes
			database creation date (with any leading zero removed), concatenated with the hour, minute, and whole-number second values of the database creation time, e.g. '1231235959'.
Series Description	(0008,103E)	3	ALWAYS: Value 'TomoTherapy Plan'
No other fields sent from the RT Series Module			

Table 50. Frame of Reference Module

Attribute Name	Element Tag	Type	Usage notes
Frame of Reference UID	(0020,0052)	1	ALWAYS: Value is the same Frame of Reference UID (0020,0052) as that found in the CT data set upon which the plan is based.
Position Reference Indicator	(0020,1040)	2	EMPTY
No other fields sent from the Frame of Reference Module			

Table 51. RT General Plan Module

Attribute Name	Element Tag	Type	Usage notes
RT Plan Label	(300A,0002)	1	ALWAYS: TomoTherapy plan label (e.g. 'Plan_01')
RT Plan Name	(300A,0003)	3	ANAP: TomoTherapy plan label (e.g. 'Plan_01')
RT Plan Description	(300A,0004)	3	ANAP: TomoTherapy plan label (e.g. 'Plan_01')
Instance Number	(0020,0013)	3	ALWAYS: Value 5
Operators' Name	(0008,1070)	2	ALWAYS: TomoTherapy user that last updated plan
RT Plan Date	(300A,0006)	2	ALWAYS: Date at which plan was last modified
RT Plan Time	(300A,0007)	2	ALWAYS: Time at which plan was last modified
Treatment Protocols	(300A,0009)	3	ANAP: List of treatment protocols, if known
Treatment Intent	(300A,000A)	3	ANAP: Treatment intent, if known
Treatment Sites	(300A,000B)	3	ANAP: List of treatment sites, if known
RT Plan Geometry	(300A,000C)	1	ALWAYS: Value 'PATIENT'

Attribute Name	Element Tag	Type	Usage notes
Referenced Structure Set Sequence	(300C,0060)	1C	ALWAYS: Number of items = 1
>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.3'
>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS: The TomoTherapy UID from the structure set upon which the plan is based
Referenced Dose Sequence	(300C,0080)	3	ALWAYS: Number of items = 1
>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.2'
>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS: The TomoTherapy UID of the dose calculated for the plan after end-of-planning
Referenced RT Plan Sequence	(300C,0002)	3	ANAP: Always present for QA plans, otherwise absent. Number of items = 1.
>Referenced SOP Class UID	(0008,1150)	1C	ALWAYS (for QA plans): Value '1.2.840.10008.5.1.4.1.1.481.5'
>Referenced SOP Instance UID	(0008,1155)	1C	ALWAYS (for QA plans): The TomoTherapy UID of the delivery plan upon which the QA plan is based
>RT Plan Relationship	(300A,0055)	1C	ALWAYS (for QA plans): Value 'VERIFIED_PLAN'
No other fields sent from the RT General Plan Module			

Table 52. RT Prescription Module

Attribute Name	Element Tag	Type	Usage notes
Prescription Description	(300A,000E)	3	English-language description of prescription, e.g. "60.0% of the NasoPh-PTV volume receives at least 65.0 Gy"
Dose Reference Sequence	(300A,0010)	3	ALWAYS: Number of items = total number of target and sensitive structure constraints that were used in the optimization, i.e. had the "Use" box checked, including those having directional or complete blocking.
>Dose Reference Number	(300A,0012)	1C	ALWAYS: Sequential number (starting at 1) identifying this dose

Attribute Name	Element Tag	Type	Usage notes
			reference. No semantics are associated with this value.
>Dose Reference Structure Type	(300A,0014)	1C	ALWAYS: Value 'VOLUME'
>Dose Reference Description	(300A,0016)	3	ALWAYS: Value is one of: <ul style="list-style-type: none"> • "Target" • "Sensitive Structure"
>Referenced ROI Number	(3006,0084)	1C	ALWAYS: ROI Number of target or sensitive structure in Structure Set Module of referenced structure set
>Dose Reference Type	(300A,0020)	1C	ALWAYS: Value 'TARGET' for tumor constraint, or 'ORGAN_AT_RISK' for sensitive structure constraint. Obtained from use in optimization process, not original ROI Interpreted Type.
>Constraint Weight	(300A,0021)	3	ALWAYS: Overall Importance of Target or sensitive structure
>Target Minimum Dose	(300A,0025)	3	ANAP: Minimum Dose to Tumor. See Table 53 for usage.
>Target Prescription Dose	(300A,0026)	3	ANAP: DVH Dose to Tumor. See Table 53 for usage.
>Target Maximum Dose	(300A,0027)	3	ANAP: Maximum Dose to Tumor. See Table 53 for usage.
>Target Underdose Volume Fraction	(300A,0028)	3	ANAP: Fraction of tumor permitted to receive less than the prescribed dose. See Table 53 for usage. Value is 1.0 – (volume percentage DVH Dose to Tumor divided by 100).
>Organ at Risk Full-volume Dose	(300A,002A)	3	ANAP: Maximum Dose to Sensitive Structure. See Table 53 for usage.
>Organ at Risk Maximum Dose	(300A,002C)	3	ANAP: DVH Dose to Sensitive Structure. See Table 53 for usage.
>Organ at Risk Overdose Volume Fraction	(300A,002D)	3	ANAP: DVH Volume percentage to Sensitive Structure, divided by 100.0. See Table 53 for usage.
>Private Creator	(300D,00xx)	3	ALWAYS: Value

Attribute Name	Element Tag	Type	Usage notes
			'TOMO_HA_01'
>Tomo Structure Blocking	(300D,xx10)	3	<p>ALWAYS: Indicates whether structure is blocked from receiving radiation. Value is one of:</p> <ul style="list-style-type: none"> • 'NONE' (no structure blocking) • 'UPSTREAM_PRIMARY' (primary fluence reaching structure before reaching the target is blocked) • 'ALL_PRIMARY' (all primary fluence is prevented from traversing the structure) <p>TOMOTHERAPY PRIVATE ATTRIBUTE.</p>
>Tomo Overlap Precedence	(300D,xx12)	3	<p>ALWAYS: Integer (1-n) used to resolve ownership of voxels from two ROIs that overlap (i.e. voxels that belong to more than one structure). In this case, voxels belong to the structure with the smallest precedence value (greatest precedence).</p> <p>TOMOTHERAPY PRIVATE ATTRIBUTE.</p>
>Tomo Target Minimum Dose Penalty	(300D,0016)	3	<p>Optimization penalty applied to not achieving Target Minimum Dose.</p> <p>TOMOTHERAPY PRIVATE ATTRIBUTE.</p>
>Tomo Target Maximum Dose Penalty	(300D,0017)	3	<p>Optimization penalty applied to not exceeding Target Maximum Dose.</p> <p>TOMOTHERAPY PRIVATE ATTRIBUTE.</p>
>Tomo Organ at Risk Maximum Dose Penalty	(300D,0018)	3	<p>Optimization penalty applied to not achieving Organ At Risk Maximum Dose. This is known as the "DVH Point Penalty" in TomoTherapy applications.</p> <p>TOMOTHERAPY PRIVATE ATTRIBUTE.</p>

Attribute Name	Element Tag	Type	Usage notes
>Tomo Organ at Risk Full-volume Dose Penalty	(300D,0019)	3	Optimization penalty applied to exceeding Organ At Risk Full-volume Dose. This is known as the sensitive structure "Max Dose Penalty" in TomoTherapy applications. TOMOTHERAPY PRIVATE ATTRIBUTE.
Private Creator	(300D,00xx)	3	ALWAYS: Value 'TOMO_HA_01'
Tomo Modulation Factor	(300D,xx14)	3	ALWAYS: Actual (calculated, not requested) Modulation Factor of plan. TOMOTHERAPY PRIVATE ATTRIBUTE.
No other fields sent from the RT Prescription Module			

Mapping from TomoTherapy Constraints to DICOM

The following table indicates the DICOM constraint-related attributes that appear in the RT Plan object as a function of the constraint type.

Table 53. TomoTherapy Constraint to DICOM Mapping

Tomo Prescription/Constraint Type	DICOM attributes Used
Tumor Minimum Dose Constraint	Tomo Target Minimum Dose Penalty Target Minimum Dose
Tumor DVH Constraint	Target Prescription Dose Target Underdose Volume Fraction
Tumor Maximum Dose Constraint	Tomo Target Maximum Dose Penalty Target Maximum Dose
Sensitive Structure DVH Point	Tomo Organ At Risk Maximum Dose Penalty Organ at Risk Maximum Dose Organ At Risk Overdose Volume Fraction
Sensitive Structure Maximum Dose Point	Tomo Organ At Risk Full-volume Dose Penalty Organ at Risk Full-volume Dose

Table 54. RT Patient Setup Module

Attribute Name	Element Tag	Type	Usage notes
Patient Setup Sequence	(300A,0180)	1	ALWAYS: Number of items = 1

Attribute Name	Element Tag	Type	Usage notes
>Patient Setup Number	(300A,0182)	1	ALWAYS: Value 1
>Patient Position	(0018,5100)	1C	ALWAYS: The Patient Position described in the referenced CT Image objects (TomoTherapy applications do not permit “flipping” of scans for planning purposes)
>Setup Technique	(300A,01B0)	3	ALWAYS: Value ‘ISOCENTRIC’
No other fields sent from the RT Patient Setup Module			

Table 55. RT Fraction Scheme Module

Attribute Name	Element Tag	Type	Usage notes
Fraction Group Sequence	(300A,0070)	1	ALWAYS: Number of items = 1
>Fraction Group Number	(300A,0171)	1	ALWAYS: Value 1
>Referenced Patient Setup Number	(300C,006A)	3	ALWAYS: Value 1
>Number of Fractions Planned	(300A,0078)	2	ALWAYS: Number of fractions (procedures) planned for delivery in Hi-ART Fractionation Panel.
>Number of Beams	(300A,0080)	1	ALWAYS: Number of fractions (procedures) planned for delivery in Hi-ART Fractionation Panel.
>Referenced Beam Sequence	(300C,0004)	1C	ALWAYS: Number of items = Number of fractions (procedures) planned for delivery in Hi-ART Fractionation Panel.
>>Referenced Beam Number	(300C,0006)	1C	ALWAYS: Value 1
>>Beam Dose	(300A,0084)	3	ALWAYS: Fraction (procedure) prescription dose in Gy
>>Beam Meterset	(300A,0086)	3	ALWAYS: Scheduled beam delivery time in minutes
>>Private Creator	(300D,00xx)	3	ALWAYS: Value ‘TOMO_HA_01’
>>Tomo Procedure UID	(300D,1020)	3	ALWAYS: Tomo UID for delivery procedure created in Hi-ART end-of-planning process. TOMOTHERAPY PRIVATE ATTRIBUTE.
>>Tomo Procedure	(300D,1022)	3	ALWAYS: Tomo Procedure

Attribute Name	Element Tag	Type	Usage notes
Number			Number for delivery procedure created in Hi-ART end-of-planning process. Note that this attribute is a string. TOMOTHERAPY PRIVATE ATTRIBUTE.
>>Tomo Procedure Date	(300D,1030)	3	ALWAYS: Date for delivery procedure in Hi-ART Fractionation Panel. TOMOTHERAPY PRIVATE ATTRIBUTE.
>>Tomo Procedure Time	(300D,1031)	3	ALWAYS: Time for delivery procedure in Hi-ART Fractionation Panel. TOMOTHERAPY PRIVATE ATTRIBUTE.
>>Tomo Gantry Period	(300D,xx40)	3	ALWAYS: Nominal gantry rotation period (in seconds) for Fraction (procedure). TOMOTHERAPY PRIVATE ATTRIBUTE.
>>Tomo Couch Speed	(300D,xx80)	3	ALWAYS: Planned couch speed in mm/sec. TOMOTHERAPY PRIVATE ATTRIBUTE.
>Number of Brachy Application Setups	(300A,00A0)	1	ALWAYS: Value 0
No other fields sent from the RT Fraction Scheme Module			

Table 56. RT Beams Module

Attribute Name	Element Tag	Type	Usage notes
Beam Sequence	(300A,00B0)	1	ALWAYS: Number of items = 1
>Beam Number	(300A,00C0)	1	ALWAYS: Value 1
>Beam Name	(300A,00C2)	3	ALWAYS: Value 'Helical TomoTherapy Beam'
>Beam Description	(300A,00C3)	3	ALWAYS: English-language description of delivery beam pitch and field size
>Beam Type	(300A,00C4)	1	ALWAYS: Value 'DYNAMIC'
>Radiation Type	(300A,00C6)	2	ALWAYS: Value 'PHOTON'
>Treatment Machine Name	(300A,00B2)	2	ALWAYS: Name of intended treatment machine
>Private Creator	(300D,00xx)	3	ALWAYS: Value 'TOMO_HA_01'
>Tomo Machine UID	(300D,xx50)	3	ALWAYS: TomoTherapy

Attribute Name	Element Tag	Type	Usage notes
			UID of intended treatment machine. TOMOTHERAPY PRIVATE ATTRIBUTE.
>Tomo Treatment Pitch	(300D,xx60)	3	ALWAYS: Distance in mm that treatment couch progresses in one gantry rotation divided by the total opening of the Y jaw pair in mm (the 'field width'). TOMOTHERAPY PRIVATE ATTRIBUTE.
>Manufacturer	(3008,0070)	3	ALWAYS: Value 'TomoTherapy Incorporated'
>Manufacturer's Model Name	(0008,1090)	3	ALWAYS: Value 'Hi-Art'
>Device Serial Number	(0018,1000)	3	ANAP: Serial Number of Hi-ART machine, if available
>Primary Dosimeter Unit	(300A,00B3)	3	ALWAYS: Value 'MINUTE'
>Source-Axis Distance	(300A,00B4)	3	ALWAYS: SAD of TomoTherapy machine
> Beam Limiting Device Sequence	(300A,00B6)	1	ALWAYS: Number of items = 2. Note that only the aperture collimator, and not the collimator leaves, is represented in this object.
>>RT Beam Limiting Device Type	(300A,00B8)	1	ALWAYS: 1 st item: Value 'X' (collimator slit length) 2 nd item: Value 'ASYMY' (jaw width)
>>Number of Leaf/Jaw Pairs	(300A,00BC)	1	ALWAYS: 1 st item: Value 1 2 nd item: Value 1
>Referenced Patient Setup Number	(300C,006A)	3	ALWAYS: Value 1
>Treatment Delivery Type	(300A,00CE)	3	ALWAYS: Value 'TREATMENT'
>Number of Wedges	(300A,00D0)	1	ALWAYS: Value 0
>Number of Compensators	(300A,00E0)	1	ALWAYS: Value 0
>Number of Boli	(300A,00ED)	1	ALWAYS: Value 0
>Number of Blocks	(300A,00F0)	1	ALWAYS: Value 0
>Final Cumulative Meterset Weight	(300A,010E)	2C	ALWAYS: Value 1.0
>Number of Control Points	(300A,0110)	1	ALWAYS: Value 2
>Control Point Sequence	(300A,0111)	1	ALWAYS: Number of items = 2

Attribute Name	Element Tag	Type	Usage notes
>>Control Point Index	(300A,0112)	1C	ALWAYS (both control points): Sequential index of control point, starting at 0
>>Cumulative Meterset Weight	(300A,0134)	2C	ALWAYS: 1 st item: Value 0 2 nd item: Value 1.0
>>Nominal Beam Energy	(300A,0114)	3	ALWAYS (first control point only): Value 6.0
>>Beam Limiting Device Position Sequence	(300A,011A)	1C	ALWAYS (first control point only): Number of items = 2. Note that only the aperture collimator, and not the collimator leaves, is represented in this object.
>>>RT Beam Limiting Device Type	(300A,00B8)	1C	ALWAYS: 1 st item: Value 'X' (collimator slit length) 2 nd item: Value 'ASYMY' (jaw width)
>>>Leaf/Jaw Positions	(300A,011C)	1C	ALWAYS: 1 st item: 2 values -200.0, 200.0 2 nd item: 2 values, Y1 (front) and Y2 (back) jaw position in mm.
>>Gantry Angle	(300A,011E)	1C	ALWAYS (first control point only): TomoTherapy uses a helical delivery where beam angles exceed 360 degrees. Gantry Angle as defined by this DICOM attribute is misleading for TomoTherapy, so the first Control Point is given a value of 0.0 and the second Control Point no value in order to satisfy DICOM requirements.
>>Gantry Rotation Direction	(300A,011F)	1C	ALWAYS (first control point only): Value 'CW'
>>Beam Limiting Device Angle	(300A,0120)	1C	ALWAYS (first control point only): Value 0.0
>>Beam Limiting Device Rotation Direction	(300A,0121)	1C	ALWAYS (first control point only): Value 'NONE'
>>Patient Support Angle	(300A,0122)	1C	ALWAYS (first control point only): Value 0.0
>>Patient Support Angle	(300A,0123)	1C	ALWAYS (first control point

Attribute Name	Element Tag	Type	Usage notes
Rotation Direction			only): Value 'NONE'
>>Table Top Eccentric Angle	(300A,0125)	1C	ALWAYS (first control point only): Value 0.0
>>Table Top Eccentric Rotation Direction	(300A,0126)	1C	ALWAYS (first control point only): Value 'NONE'
>>Table Top Vertical Position	(300A,0128)	2C	EMPTY (first control point only, absent for all others)
>>Table Top Longitudinal Position	(300A,0129)	2C	EMPTY (first control point only, absent for all others)
>>Table Top Lateral Position	(300A,012A)	2C	EMPTY (first control point only, absent for all others)
>>Isocenter Position	(300A,012C)	2C	ALWAYS (first control point only): The reference planning isocenter for the TomoTherapy plan.
No other fields sent from the RT Beams Module			

Table 57. Approval Module

Attribute Name	Element Tag	Type	Usage notes
Approval Status	(300E,0002)	1	ALWAYS: Value 'APPROVED'
Review Date	(300E,0004)	2C	ALWAYS: Date on which plan was approved (equal to date on which plan was last modified).
Review Time	(300E,0005)	2C	ALWAYS: Time at which plan was approved (equal to time at which plan was last modified).
Reviewer Name	(300E,0008)	2C	ALWAYS: Name of TomoTherapy user who approved plan for treatment (i.e. who last modified the plan).
No other fields sent from the Approval Module			

Table 58. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	ALWAYS: Value '1.2.840.10008.5.1.4.1.1.481.5'
SOP Instance UID	(0008,0018)	1	ALWAYS: The TomoTherapy UID from the plan being transmitted
Specific Character Set	(0008,0005)	1C	ABSENT. TomoTherapy does not currently support

Attribute Name	Element Tag	Type	Usage notes
			expanded or replacement character sets.
Instance Creation Date	(0008,0012)	3	ALWAYS: Date of actual object construction (object send time)
Instance Creation Time	(0008,0013)	3	ALWAYS: Time of actual object construction (object send time)
No other fields sent from the SOP Common Module			

8.1.2 Usage of Attributes from Received IODs

8.1.2.1 CT Image Storage Class

The following tables identify the entities for each IOD module for a CT Image Store operation. The tables indicate which IOD Entities have fields that will be stored in the TomoTherapy Data Server upon successful completion of the C-STORE operation.

Table 59. CT Image IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 60
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 61
	Patient Study	U	Table 62
	Clinical Trial Study	U	Not used
Series	General Series	M	Table 63
	Clinical Trial Series	U	Not used
Frame of Reference	Frame of Reference	M	Table 64
Equipment	General Equipment	M	Table 65
Image	General Image	M	Table 66
	Image Plane	M	Table 67
	Image Pixel	M	Table 68
	Contrast/bolus	C	Not used
	CT Image	M	Table 69
	Overlay Plane	U	Not used
	VOI LUT	U	Not used
	SOP Common	M	Table 70

Patient Association

If a received patient module matches a patient record in the TomoTherapy Data Server, TomoProvider does not update any fields for that record, even if the received elements comprise a superset of information already in the Data Server. A received patient module is considered to match an existing patient record if the patient ID is identical and if the patient name fields match. Two patient names are considered to match if both of the following conditions are true:

- Both names have the same number of name subparts (character strings separated by punctuation or space)
- All the name parts in one patient name match exactly one name part in the other patient name without respect to case.

If there is no patient match, a new patient record is created in the database, and all supplied optional fields shall be recorded with the new patient record.

If a patient name is “_phantom”, TomoProvider performs the following:

- CT images are put into the single phantom patient on the TomoTherapy Data Server. This phantom patient has an automatically generated patient ID of “phantomMRN”.
- A new disease is created, using the patient ID as the disease name.
- The received CT image is placed into the new disease under the single phantom patient.

Table 60. Patient Module

Attribute Name	Element Tag	Type	Usage notes
Patient’s Name	(0010,0010)	2	Required field: must be non-blank
Patient ID	(0010,0020)	2	Required field: must be non-blank
Patient’s Birth Date	(0010,0030)	2	Optional field: stored if present.
Patient’s Sex	(0010,0040)	2	Optional field: stored if present.
Patient’s Birth Time	(0010,0032)	3	Optional field: stored if present.
Other Patient IDs	(0010,1000)	3	Optional field: stored if present.
Other Patient Names	(0010,1001)	3	Optional field: stored if present.
Ethnic Group	(0010,2160)	3	Optional field: stored if present.
Patient Comments	(0010,4000)	3	Optional field: stored if present.

Table 61. General Study Module

Attribute Name	Element Tag	Type	Usage notes
Study Instance UID	(0020,000D)	1	Required field: used for sorting items in the transmission for processing.
Referring Physician’s Name	(0008,0090)	2	Optional field: if present and field Physician(s) of Record is not present, it is used for the patient’s oncologist
Study ID	(0020,0010)	2	Optional field: is valued, used for the disease name
Physician(s) of Record	(0008,1048)	3	Optional field: if present, first physician is used for the patient’s oncologist
No other fields used or stored from the General Study Module			

Table 62. Patient Study Module

Attribute Name	Element Tag	Type	Usage notes
Admitting Diagnoses Description	(0008,1080)	3	Optional field: stored if present.
Patient's Age	(0010,1010)	3	Optional field: stored if present.
Patient's Size	(0010,1020)	3	Optional field: stored if present.
Patient's Weight	(0010,1030)	3	Optional field: stored if present.
Additional Patient's History	(0010,21B0)	3	Optional field: stored if present.
No other fields used or stored from the Patient Study Module			

Table 63. General Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	Required field: must be 'CT'
Series Instance UID	(0020,000E)	1	Required field: always stored as the originating UID of the series (but is not used for the Tomo database UID)
Patient Position	(0018,5100)	2C	Required field: must be one of HFS, FFS, HFP, or FFP; always stored; must be the same for all slices in the series.
No other fields used or stored from the General Series Module			

Table 64. Frame of Reference Module

Attribute Name	Element Tag	Type	Usage notes
Frame of Reference UID	(0020,0052)	1	Required field: always stored with the series.
No other fields used or stored from the Frame of Reference Module			

Table 65. General Equipment Module

Attribute Name	Element Tag	Type	Usage notes
Manufacturer	(0008,0070)	2	Optional field: stored if present.
Institution Name	(0008,0080)	3	Optional field: stored if present.
Manufacturer's Model	(0008,1090)	3	Optional field: stored if

Attribute Name	Element Tag	Type	Usage notes
Name			present.
Device Serial Number	(0018,1000)	3	Optional field: stored if present.
Software Versions	(0018,1020)	3	Optional field: only the first item in the series will be kept
Pixel Padding Value	(0028,0120)	3	Optional field: stored if present; must be the same for all slices in the series.
No other fields used or stored from the General Equipment Module			

Table 66. General Image Module

Attribute Name	Element Tag	Type	Usage notes
Image Type	(0008,0008)	3	See CT Image Module
Acquisition Date	(0008,0022)	3	Optional field: stored if present.
Acquisition Time	(0008,0032)	3	Optional field: stored if present.
No other fields used or stored from the General Image Module			

Table 67. Image Plane Module

Attribute Name	Element Tag	Type	Usage notes
Pixel Spacing	(0028,0030)	1	Required field: the variation across slices for this field permitted for a valid image series is +/-0.005cm / rows (for Y pixel spacing) and +/-0.005cm / columns (for X pixel spacing)
Image Orientation (Patient)	(0020,0037)	1	Required field: Angles corresponding to direction cosines must be less than +/-0.6 degrees off vertical and no more than +/-0.6 degrees off perpendicular to the Z plane
Image Position (Patient)	(0020,0032)	1	Required field: The variation across slices for the horizontal value must be less than 0.01 cm. The variation across slices for the vertical value must be less than the value specified by the 'VerticalDeviation' configuration parameter. See Section 4.4.2.

Attribute Name	Element Tag	Type	Usage notes
Device Serial Number	(0018,1000)	3	Optional field: stored if present.
Software Versions	(0018,1020)	3	Optional field: only the first item in the series will be kept
Pixel Padding Value	(0028,0120)	3	Optional field: see description in General Equipment Module
No other fields used or stored from the Image Plane Module			

Table 68. Image Pixel Module

Attribute Name	Element Tag	Type	Usage notes
Samples per Pixel	(0028,0002)	1	See CT Image Module
Rows	(0028,0010)	1	Required field: must be identical for all images in the series
Columns	(0028,0011)	1	Required field: must be equal to rows for all images in the series (i.e., images must be square)
Bits Allocated	(0028,0100)	1	See CT Image Module
Bits Stored	(0028,0101)	1	See CT Image Module
High Bit	(0028,0102)	1	See CT Image Module
Pixel Representation	(0028,0103)	1	Required field: must be identical for all images in the series
Pixel Data	(7FE0,0010)	1	Required field
No other fields used or stored from the Image Pixel Module			

Image Dimensions

The TomoTherapy HI-ART System supports planning based on square image slices only, i.e. where Rows (0028,0010) and Columns (0028,0011) have equal values and the two values of Pixel Spacing (0028,0030) are also equal. Although CT scanners normally generate square images, these images may be cropped to rectangles using a CT simulation or treatment planning system. When cropping images, be sure that the resulting dimensions are square. In addition, for maximum flexibility during the optimization process, the number of pixels in the rows and columns should also be divisible by 4.

Table 69. CT Image Module

Attribute Name	Element Tag	Type	Usage notes
Image Type	(0008,0008)	1	Required field: AXIAL must be present in the third item of the sequence for all slices

Attribute Name	Element Tag	Type	Usage notes
Samples per Pixel	(0028,0002)	1	Required field
Bits Allocated	(0028,0100)	1	Required field: must be identical for all images in the series
Bits Stored	(0028,0101)	1	Required field: must be identical for all images in the series
High Bit	(0028,0102)	1	Required field: must be identical for all images in the series
Rescale Intercept	(0028,1052)	1	Required field: must be identical for all images in the series
Rescale Slope	(0028,1053)	1	Required field: must be identical for all images in the series
KVP	(0018,0060)	2	Optional field: if present and equal to or greater than 6000kV, image is considered to be a TomoImage; otherwise it is a KVCT image
No other fields used or stored from the Image Pixel Module			

Table 70. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	Required field: Used to verify object type
SOP Instance UID	(0008,0018)	1	Required field
No other fields used or stored from the SOP Common Module			

8.1.2.2 RT Structure Set Storage Class

The following tables identify the entities for each IOD module for an RT Structure Set store operation. The tables indicate which IOD Entities have fields that will be stored in the TomoTherapy Data Server upon successful completion of the C-STORE operation.

Table 71. RT Structure Set IOD Entities

Entity Name	Module Name	Usage	Reference
Patient	Patient	M	Table 72
	Clinical Trial Subject	U	Not used
Study	General Study	M	Table 73
	Patient Study	U	Not used
	Clinical Trial Study	U	Not used
Series	RT Series	M	Table 74
	Clinical Trial Series	U	Not used
Equipment	General Equipment	M	Not used
Structure Set	Structure Set	M	Table 75
	ROI Contour	M	Table 76
	RT ROI Observations	M	Table 77
	Approval	U	Not used
	Audio	U	Not used
	SOP Common	M	Table 78

Table 72. Patient Module

Attribute Name	Element Tag	Type	Usage notes
Patient's Name	(0010,0010)	2	Required field: must be non-blank and verified to closely match a patient name in the TomoTherapy Data Server
Patient ID	(0010,0020)	2	Required field: must be non-blank and verified to exactly match a patient ID in the TomoTherapy Data Server
No other fields used or stored from the Patient Module			

Table 73. General Study Module

Attribute Name	Element Tag	Type	Usage notes
Study Instance UID	(0020,000D)	1	Required field: used for sorting items in the transmission for processing.
No other fields used or stored from the General Study Module			

Table 74. RT Series Module

Attribute Name	Element Tag	Type	Usage notes
Modality	(0008,0060)	1	Required field: must be RTSTRUCT
Series Instance UID	(0020,000E)	1	Required field
No other fields used or stored from the RT Series Module			

Table 75. Structure Set Module

Attribute Name	Element Tag	Type	Usage notes
Structure Set Label	(3006,0002)	1	Required field
Referenced Frame of Reference Sequence	(3006,0010)	3	Required field
> Frame of Reference UID	(0020,0052)	1C	Required field
>RT Referenced Study Sequence	(3006,0012)	3	Required field
>>RT Referenced Series Sequence	(3006,0014)	1C	Required field
>>>Series Instance UID	(0020,000E)	1C	Required field: must be identical to the Series Instance UID from a transmitted CT Image Series
Structure Set ROI Sequence	(3006,0020)	3	Required field
>ROI Number	(3006,0022)	1C	Required field
>Referenced Frame of Reference UID	(3006,0024)	1C	Required field: must match one of the items in Referenced Frame of Reference Sequence, and be identical for all ROIs
>ROI Name	(3006,0026)	2C	Required field
No other fields used or stored from the Structure Set Module			

Table 76. ROI Contour Module

Attribute Name	Element Tag	Type	Usage notes
ROI Contour Sequence	(3006,0039)	1	Required field
>Referenced ROI Number	(3006,0084)	1	Required field
>ROI Display Color	(3006,002A)	3	Optional field: if not present, one will be automatically assigned
>Contour Sequence	(3006,0040)	3	Optional field
>>Contour Data	(3006,0050)	1C	Required field if Contour Sequence present: all contour points must be in the

Attribute Name	Element Tag	Type	Usage notes
			image volume represented by the referenced CT Image series and lie in the same axial plane.
No other fields used or stored from the ROI Contour Module			

Points of Interest

ROI Contour Sequence items that are points (i.e. with one contour containing one point) are not processed. The TomoTherapy Hi-ART System does not store point ROIs received in DICOM RT Structure Set objects.

Table 77. RT ROI Observations Module

Attribute Name	Element Tag	Type	Usage notes
RT ROI Observations Sequence	(3006,0080)	1	Required field
>Referenced ROI Number	(3006,0084)	1	Required field
>RT ROI Interpreted Type	(3006,00A4)	2	Optional field: defaults to null-valued if not present or not one of EXTERNAL, PTV, CTV, GTV, AVOIDANCE, ORGAN, or CAVITY.
No other fields used or stored from the RT ROI Observations Module			

Table 78. SOP Common Module

Attribute Name	Element Tag	Type	Usage notes
SOP Class UID	(0008,0016)	1	Required field: Used to verify object type
SOP Instance UID	(0008,0018)	1	Required field
No other fields used or stored from the SOP Common Module			

8.1.3 Attribute Mapping

In some cases attributes received by the TomoProvider AE are either not stored, or converted to a different enumeration or scaling prior to storage in the TomoTherapy Data Server. When CT Image or RT Structure Set objects are re-exported, these attributes will either be missing from the exported object, or have values that may have been changed. These mappings are documented in Sections 8.1.1 and 8.1.2 in the attribute descriptions.

8.1.4 Coerced/Modified Fields

Coercion: When an RT Structure Set or RT Plan object is received by the TomoProvider SCP, an attempt is made to match the Patient ID (exactly) and Patient Name (closely), as described in Section 8.1.2.1. If a match is made, the Patient Name is coerced (if necessary), and all other attributes in the Patient and Study entities are coerced to the values that were present in the CT objects transferred previously.

Table 79. Coerced Fields for RT Structure Set and RT Plan Import

Attribute Name	Element Tag	Coercion Conditions
Patient's Name	(0010,0010)	Coerced to Patient Name already stored in Data Server if match conditions described in 8.1.2.1 are satisfied.
Patient ID	(0010,0020)	Never Coerced
All other Patient and Study level attributes		Coerced to corresponding attribute value already stored in Data Server if match conditions described in 8.1.2.1 are satisfied.

Modification: Modification of attributes prior to storage in the TomoTherapy Data Server is noted throughout Section 8.1.2 when they occur.

8.2 Data Dictionaries

8.2.1 Private Attributes

The Private Attributes added to created SOP Instances are listed in the following table. TomoTherapy Hi-ART reserves blocks of private attributes in group 300D only. Further details on usage of these private attributes are contained in Section 8.1.

Table 80. TomoTherapy Private Attributes

Tag	Attribute Name	VR	VM
(300D,00xx)	Private Creator	LO	1
(300D,xx10)	Tomo Structure Blocking	CS	1
(300D,xx12)	Tomo Overlap Precedence	IS	1
(300D,xx14)	Tomo Modulation Factor	DS	1
(300D,xx16)	Tomo Target Minimum Dose Penalty	IS	1

Tag	Attribute Name	VR	VM
(300D,xx17)	Tomo Target Maximum Dose Penalty	IS	1
(300D,xx18)	Tomo Organ At Risk Maximum Dose Penalty	IS	1
(300D,xx19)	Tomo Organ At Risk Full Volume Dose Penalty	IS	1
(300D,xx20)	Tomo Procedure UID	UI	1
(300D,xx22)	Tomo Procedure Number	SH	1
(300D,xx30)	Tomo Procedure Date	DT	1
(300D,xx31)	Tomo Procedure Time	TM	1
(300D,xx40)	Tomo Gantry Period	DS	1
(300D,xx50)	Tomo Machine UID	UI	1
(300D,xx60)	Tomo Treatment Pitch	DS	1
(300D,xx80)	Tomo Couch Speed	DS	1

8.3 Coded Terminology and Templates

TomoTherapy applications do not require support for Coded Terminology and Templates.

8.4 Grayscale Image Consistency

TomoTherapy applications do not support the DICOM Grayscale Standard Display Function.

8.5 Standard Extended/Specialized/Private SOPs

The RT Plan objects and RT Beams Session Record objects created by the TomoTherapy HI-ART System are Standard Extended objects. Extension is via addition of private attributes listed in Table 80 and described in Sections 8.1.1.

There are no specialized or private SOP classes implemented by TomoTherapy applications.

8.6 Private Transfer Syntaxes

TomoTherapy applications do not implement any private transfer syntaxes.