ACC, HIMSS and RSNA

Integrating the Healthcare Enterprise

# IHE Cardiology Technical Framework

# Supplement 2006-2007

# Stress Testing Workflow Integration Profile (STRESS)

**Draft for Public Comment**

**Comments due May 19, 2006**

# 1 Foreword

Integrating the Healthcare Enterprise (IHE) is an initiative designed to stimulate the integration of the information systems that support modern healthcare institutions. Its fundamental objective is to ensure that in the care of patients all required information for medical decisions is both correct and available to healthcare professionals. The IHE initiative is both a process and a forum for encouraging integration efforts. It defines a technical framework for the implementation of established messaging standards to achieve specific clinical goals. It includes a rigorous testing process for the implementation of this framework. And it organizes educational sessions and exhibits at major meetings of medical professionals to demonstrate the benefits of this framework and encourage its adoption by industry and users.

The approach employed in the IHE initiative is not to define new integration standards, but rather to support the use of existing standards, HL7, DICOM, IETF, and others, as appropriate in their respective domains in an integrated manner, defining configuration choices when necessary. IHE maintain formal relationships with several standards bodies including HL7, DICOM and refers recommendations to them when clarifications or extensions to existing standards are necessary.

This initiative has numerous sponsors and supporting organizations in different medical specialty domains and geographical regions. In North America the primary sponsors are the American College of Cardiology (ACC), the Healthcare Information and Management Systems Society (HIMSS) and the Radiological Society of North America (RSNA). IHE Canada has also been formed. IHE Europe (IHE-EUR) is supported by a large coalition of organizations including the European Association of Radiology (EAR) and European Congress of Radiologists (ECR), the Coordination Committee of the Radiological and Electromedical Industries (COCIR), Deutsche Röntgengesellschaft (DRG), the EuroPACS Association, Groupement pour la Modernisation du Système d'Information Hospitalier (GMSIH), Société Francaise de Radiologie (SFR), Società Italiana di Radiologia Medica (SIRM), the European Institute for health Records (EuroRec), and the European Society of Cardiology (ESC). In Japan IHE-J is sponsored by the Ministry of Economy, Trade, and Industry (METI); the Ministry of Health, Labor, and Welfare; and MEDIS-DC; cooperating organizations include the Japan Industries Association of Radiological Systems (JIRA), the Japan Association of Healthcare Information Systems Industry (JAHIS), Japan Radiological Society (JRS), Japan Society of Radiological Technology (JSRT), and the Japan Association of Medical Informatics (JAMI). Other organizations representing healthcare professionals are invited to join in the expansion of the IHE process across disciplinary and geographic boundaries.

The IHE Technical Frameworks for the various domains (IT Infrastructure, Cardiology, Laboratory, Radiology, etc.) define specific implementations of established standards to achieve integration goals that promote appropriate sharing of medical information to support optimal patient care. It is expanded annually, after a period of public review, and maintained regularly through the identification and correction of errata. The current version for these Technical Frameworks may be found at www.ihe.net.

The IHE Technical Framework identifies a subset of the functional components of the healthcare enterprise, called IHE Actors, and specifies their interactions in terms of a set of coordinated, standards-based transactions. It describes this body of transactions in progressively greater depth. The volume I provides a high-level view of IHE functionality, showing the transactions organized into functional units called Integration Profiles that highlight their capacity to address specific clinical needs. The subsequent volumes provide detailed technical descriptions of each IHE transaction.

**This supplement to the IHE Cardiology Technical Framework v2 is submitted for Public Comment between April 17, 2006 and May 19, 2006.**

**Comments shall be submitted before May 19, 2006 to:**

**http://forums.rsna.org**

**Under the "*IHE*" forum, select the "*IHE Cardiology Technical Framework Supplements 2006*" sub-forum.**

**The IHE Cardiology Technical Committee will address these comments and publish the Trial Implementation version in June 2006.**

## 2 Introduction to this Supplement

This Supplement adds a new Stress Testing Workflow Integration Profile to the IHE Cardiology Technical Framework. The Stress Profile defines a means of ordering and performing cardiac stress tests involving stress ECG, echocardiographic, and/or nuclear imaging components. The profile is aligned with the Actors and Transactions of the Echocardiography Workflow and Scheduled Workflow Integration Profiles, so that a common infrastructure can be used in an integrated manner.

### 2.1 Selection of the Standard

The IHE Cardiology Technical Committee has selected the use of DICOM to manage workflow for stress testing in this profile. We seriously considered the alternative of an HL7-based workflow management environment, and devoted considerable effort to developing a profile for such. However, after comparing DICOM to HL7 for the use cases of this profile, we believe DICOM is the best choice for the long term for the following principal reasons:

- HL7 does not have a strong query model for managing diagnostic procedure worklists. It has a general outline for queries, but each use requires a unique profile specifying query keys, query wildcards, required and optional data elements, response messages, etc. The effort to develop an interoperable profile is comparable to defining a major new message exchange standard. However, the DICOM standard Modality Worklist is already fully defined and profiled in the IHE Technical Framework.
- Since an HL7 query profile would be new, there would be no implementation experience available to draw on. In contrast, DICOM Modality Worklist has been in use in products for almost a decade, and there is a full set of MESA test tools available to test it.
- The ECG component of stress testing must be coordinated with the imaging (echo or nuclear) component. This is easier accomplished if the workflow management uses identical procedure management concepts and the same message standards. Since the stress imaging side is already managed using DICOM through defined IHE profiles, applying that to the stress ECG side make the job of the department management system much simpler.

## 2.2 Stress Evidence Document Content

While this profile specifies the use of DICOM Structure Report (SR) Evidence Documents to convey stress measurements, it has not specified Templates for the content of ECG or Nuclear stress evidence documents. The stress echocardiography Template is specified in the Echo Evidence Option of the Evidence Documents Profile (see IHE Cardiology Technical Framework Volume 1, Section 7.2).

It is the expectation of the IHE Cardiology Technical Committee that the necessary SR Templates for this use will be developed by DICOM WG-01 during the course of this year, and will be available for profiling in IHE for Cardiology Year 4 (2007-2008). At that time, additional options will be specified for the Evidence Documents Profile paralleling the options for Cath and Echo.

## 2.3 Open Issues for Public Comment

1. The IHE Cardiology Technical Committee has chosen the DICOM standard for Stress ECG workflow management and Stress ECG data. Is DICOM an appropriate standard for Stress ECG workflow management? Is DICOM an appropriate standard for Stress ECG data (waveforms, measurements, annotations)?
2. The profile presumes that an Acquisition Modality in a DICOM workflow will produce acquisition data in a DICOM format. The IHE Cardiology Technical Committee has chosen to allow multiple options. Should there be any assertions that an ECG Stress Monitor as an Acquisition Modality must produce DICOM ECG waveforms? Would the production of Encapsulated PDF objects be sufficient? Even if we agree that DICOM ECG waveforms are required, can we allow such systems to participate in the DICOM workflow

 

and not produce DICOM waveforms (perhaps as a first year demonstration waiver)? (Compare the waiver on DICOM objects from Hemodynamic Monitors as an Acquisition Modality in the existing Cath Profile – IHE Cardiology Technical Framework Volume 1, Section 3.1, note to Table 3.1-1.)

3. The IHE Cardiology Technical Committee has chosen to not specialize the Image Query transaction for objects in this profile Should the Image Query transaction be specialized to require the return of instance date and time? Argument for: it allows the querying system to get a picture of the time stamped objects of both ECG and imaging modalities before retrieving specific objects. Arguments against: It is unlikely that any objects of a stress test would be retrieved individually – they always are viewed in the context of rest **and** stress data, so a workstation should just retrieve the entire series or study, and can display all the significant attributes of the objects (time, protocol stage, patient state, etc.).
4. The IHE Cardiology Technical Committee has chosen to require the Image Display actor to support the display of related images. Is it appropriate to require Image Display actors claiming this profile to support all stress data types - ECG waveforms, echo images, **and** nuclear images? (See proposed Volume 1 Table 3.2-1 and note 2 to that table.)
5. The IHE Cardiology Technical Committee has chosen to include the Report Creator in this profile. Is it appropriate to include the Report Creator in this Profile, similar to its inclusion in the Evidence Documents profile? (I.e., no transactions, but using data from retrieved objects in a report submitted through another profile, e.g., DRPT. See text at end of proposed Volume 1 Section 8.1.) Is it appropriate for the Profile to call out Report Creator grouping with the acquisition modality, recognizing that this is common in stress ECG monitoring systems?
6. What protocol concepts/codes should be specified for pharmacological stress tests? (See proposed Volume 2 Table 4.2-12.)
7. Should this profile include any specification with respect to other stress imaging modalities like MR?

# Additions to IHE Cardiology Technical Framework Volume 1

*Add to Section 1.7*

- The Stress Testing Workflow Profile provides the mechanism for ordering and collecting multi-modality data during diagnostic Stress testing procedures.

*Add to Section 2.1*

**Table 2-1 Integration Profile Dependencies**

| | | | |
|---|---|---|---|
| Stress Testing Workflow | ITI-TF Consistent Time | The DSS/Order Filler and the Acquisition Modality actors are required to be grouped with Time Client actors. | |
| | RAD-TF Nuclear Medicine | The Image Manager/Image Archive and Image Display actors shall support the Nuclear Medicine Profile. | |
| | CARD-TF Echocardiography Workflow | The Image Manager/Image Archive and Image Display actors shall support the Echocardiography Workflow Profile. | |

*Add to Section 2.2*

### 2.2.6 Stress Testing Workflow

The Stress Testing Workflow Integration Profile describes the workflow associated with managing cardiac stress test procedures. This profile deals with patient identifiers, orders, scheduling, status reporting, multi-stage exams, and data storage. It specifies the scheduling and coordination of procedure data across a variety of imaging, ECG acquisition, measurement, and analysis systems, and its reliable storage in an archive from where it is available to support subsequent workflow steps, such as reporting.

*Add to Section 2.3*

**Table 2.3-1 Integration Profile Actors**

| Integration Profile / Actor | CATH | ECHO | ECG | DRPT | ED | Stress |
|---|---|---|---|---|---|---|
| Acquisition Modality | X | X | | | X | **X** |
| ADT Patient Registration | X | X | | | | **X** |
| Department System Scheduler/Order Filler | X | X | | | | **X** |
| Evidence Creator | X | X | | | X | **X** |
| Image Archive | X | X | | | X | **X** |
| Image Display | X | X | | | X | **X** |
| Image Manager | X | X | | | X | **X** |
| Order Placer | X | X | | | | **X** |
| Performed Procedure Step Manager | X | X | | | | **X** |
| Report Creator | | | | X | X | **X** |
| Report Manager | | | | X | | |
| Report Reader | | | | X | | |
| Report Repository | | | | X | | |
| Enterprise Report Repository | | | | X | | |
| Time Client | (note 1) | | | | | **(note 1)** |
| Display | | | X | | | |
| Information Source | | | X | (note 2) | | |

Notes: 1. The Time Client actor is not formally part of the Cath **and Stress** Workflow Profile**s**, but it must be grouped with certain actors in ~~that~~ **those** Profile**s**.

*Add to Section 2.4*

**Table 2.4-1. Integration Profile Transactions**

| Integration Profile / Transaction | CATH | ECHO | ECG | DRPT | ED | Stress |
|---|---|---|---|---|---|---|
| Patient Registration [RAD-1] | X | X | | | | **X** |
| Placer Order Management [RAD-2] | X | X | | | | **X** |
| Filler Order Management [RAD-3] | X | X | | | | **X** |
| Procedure Scheduled [RAD-4] | X | X | | | | **X** |
| Query Modality Worklist [RAD-5] | X | X | | | | **X** |
| Modality Procedure Step In Progress [CARD-1] | X | X | | | | **X** |

| Transaction \ Integration Profile | CATH | ECHO | ECG | DRPT | ED | **Stress** |
|---|---|---|---|---|---|---|
| Modality Procedure Step Completed [RAD-7] | X | X | | | | **X** |
| Modality Images/Evidence Stored [CARD-2] | X | X | | | X | **X** |
| Storage Commitment [CARD-3] | X | X | | X | X | **X** |
| Patient Update [RAD-12] | X | X | | | | **X** |
| Procedure Update [RAD-13] | X | X | | | | **X** |
| Query Images [RAD-14] | X | X | | | | **X** |
| Query Evidence Documents [RAD-44] | | | | | X | |
| Retrieve Images/Evidence [CARD-4] | X | X | | | | **X** |
| Instance Availability Notification [RAD-49] | X | X | | | | **X** |
| Maintain Time [ITI-1] | (note 1) | | | | | **(note 1)** |
| Retrieve Specific Info for Display [ITI-11] | | | X | (note 2) | | |
| Retrieve ECG List [CARD-5] | | | X | | | |
| Retrieve ECG Document for Display [CARD-6] | | | X | | | |
| Encapsulated Report Submission [CARD-7] | | | | X | | |
| Report Reference Submission [CARD-8] | | | | X | | |
| Encapsulated Report Storage [CARD-9] | | | | X | | |
| Encapsulated Report Query [CARD-10] | | | | X | | |
| Encapsulated Report Retrieve [CARD-11] | | | | X | | |
| Retrieve Document for Display [ITI-12] | | | | (note 2) | | |

Notes: 1. The Maintain Time transaction is not formally part of the Cath **and Stress** Workflow Profile**s**, but it is required for the Time Client actor grouped with certain actors in ~~that~~ **those** Profile**s**.

*Add to Section 2.5*

In general, a product implementation may incorporate any single actor or combination of actors. However, in the cases specified below, the implementation of one actor requires the implementation of one or more additional actors:

- The Image Archive shall be grouped with the Image Manager, and the Image Manager shall be grouped with the Image Archive.
- The Image Manager participating in Cath**, ~~Workflow or~~** Echo**, or Stress** Workflow Integration Profiles shall be grouped with a Performed Procedure Step Manager. The grouped Performed Procedure Step Manager shall be capable of being disabled via configuration.

- The Department System Scheduler/Order Filler participating in Cath**, ~~Workflow or~~** Echo**, or Stress** Workflow shall be grouped with a Performed Procedure Step Manager. The grouped Performed Procedure Step Manager shall be capable of being disabled via configuration.
- The DSS/Order Filler and Modality Acquisition Actors participating in Cath **or Stress** Workflow Integration Profile**s** shall be grouped with the Time Client Actor of the Consistent Time Profile.
- The Report Repository Actor participating in Displayable Reports Integration Profile shall be grouped with the Information Source Actor of the Retrieve Information for Display Profile.
- The Report Manager Actor participating in Displayable Reports Integration Profile shall be grouped with the Report Repository Actor of that Profile, unless it supports the DICOM Storage Option.
- The Report Repository Actor participating in Displayable Reports Integration Profile shall be grouped with the Report Manager Actor of that Profile, unless it supports the DICOM Storage Option.

*Add new Section 8*

# 8 Stress Testing Workflow (Stress)

The Stress Testing Workflow Integration Profile describes the workflow associated with cardiac stress test procedures. This profile deals with patient identifiers, orders, scheduling, status reporting, multi-stage exams, and data storage. It specifies the scheduling and coordination of procedure data across a variety of imaging, ECG acquisition, measurement, and analysis systems, and its reliable storage in an archive from where it is available to support subsequent workflow steps, such as reporting.

This profile has much in common with the IHE Radiology Scheduled Workflow and Patient Information Reconciliation Integration Profiles, but deals more explicitly with the multi-modality coordination, and with stress-specific data requirements. See **Rad TF-1: 3.4** for the integrated workflow data model adopted by the IHE Technical Framework for HL7 messages and DICOM information objects. This data model offers three major levels of control for workflow:

- **Order**: A request for a Departmental Service
- **Requested Procedure**: Unit of work resulting in one or more reports, with associated codified, billable acts.
- **Scheduled and Performed Procedure Step**: the smallest unit of work in the workflow that is scheduled (work to do) or performed (work done).

A clear understanding of the workflow data model is essential to interpreting the Stress Profile. Additional information may be found in Appendix B.

Although the major cases for stress testing workflow are described in the following subsections, it is beneficial to also see the corresponding workflows in radiology. Rad TF-1: 3.3 has a description of the "normal" scheduled workflow when all three levels of control in the data model are fully utilized for known patients.

## 8.1 Actors/Transactions

Figure 8.1-1 diagrams the actors involved with this profile and the transactions between actors.

Note that this diagram maintains the actor and transaction names specified in the Radiology Technical Framework (RAD-TF) for consistency of definitions. In particular, note that the Image Manager / Image Archive and Image Display are required in this profile to support not just images, but also waveforms and structured reports.

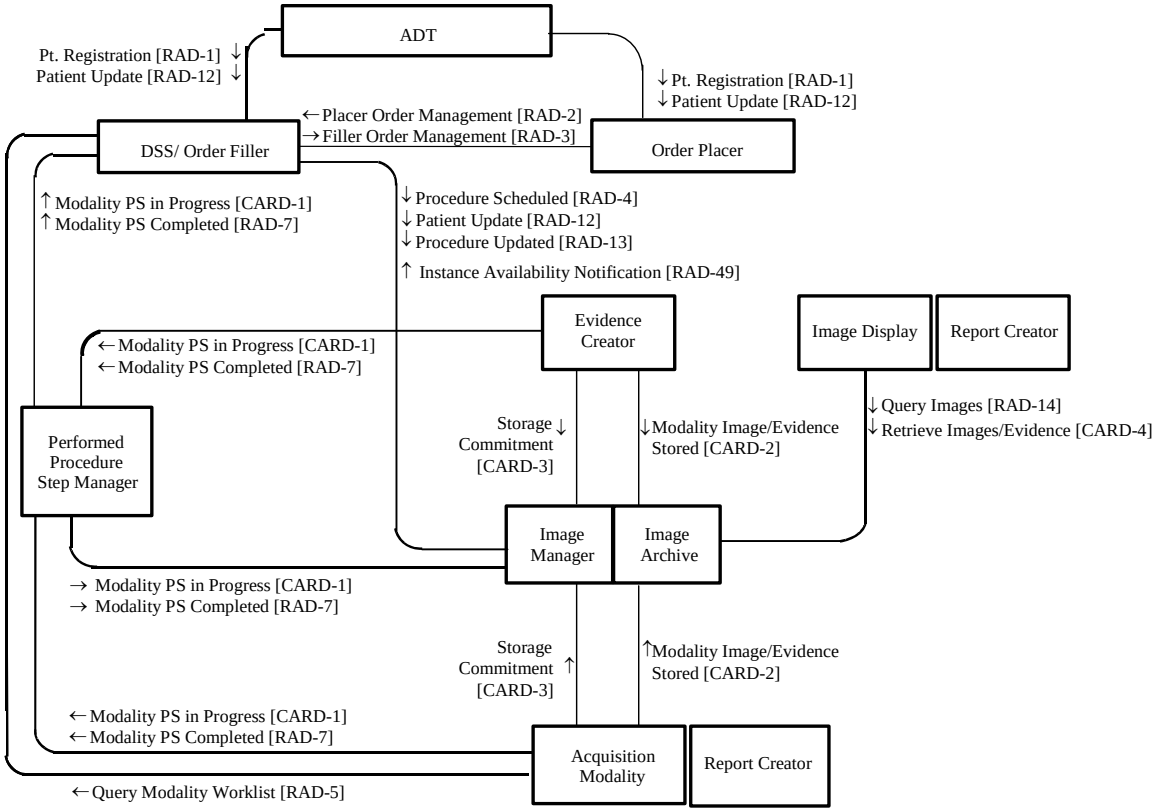


**Figure 8.1-1. Stress Testing Workflow Diagram**

Table 8.1-1 lists the transactions for each actor directly involved in the Stress Profile. In order to claim support of this Integration Profile, an implementation must perform the required transactions (labeled "R"). Transactions labeled "O" are optional. A complete list of options defined by this Integration Profile that implementations may choose to support is listed in Section 8.2.

**Table 8.1-1. Stress Workflow - Actors and Transactions**

| Actors | Transactions | Optionality | Section |
|---|---|---|---|
| ADT Patient Registration | Patient Registration [RAD-1] | R | RAD-TF 2: 4.1 |
| | Patient Update [RAD-12] | R | RAD-TF 2: 4.12 |
| Order Placer | Patient Registration [RAD-1] | R | RAD-TF 2: 4.1 |
| | Patient Update [RAD-12] | R | RAD-TF 2: 4.12 |
| | Placer Order Management [RAD-2] | R | RAD-TF 2: 4.2 |
| | Filler Order Management [RAD-3] | R | RAD-TF 2: 4.3 |
| Department System Scheduler/ Order Filler | Patient Registration [RAD-1] | R | RAD-TF 2: 4.1 |
| | Patient Update [RAD-12] | R | RAD-TF 2: 4.12 |
| | Placer Order Management [RAD-2] | R | RAD-TF 2: 4.2 |
| | Filler Order Management [RAD-3] | R | RAD-TF 2: 4.3 |
| | Procedure Scheduled [RAD-4] | R | RAD-TF 2: 4.4 |
| | Query Modality Worklist [RAD-5] | R | RAD-TF 2: 4.5 |
| | Modality Procedure Step In Progress [CARD-1] | R | CARD-TF 2: 4.1 |
| | Modality Procedure Step Completed [RAD-7] | R | RAD-TF 2: 4.7 |
| | Procedure Updated [RAD-13] | R | RAD-TF 2: 4.13 |
| | Instance Availability Notification [RAD-49] | O | RAD-TF 3: 4.49 |
| Acquisition Modality | Query Modality Worklist [RAD-5] | R | RAD-TF 2: 4.5 |
| | Modality Procedure Step In Progress [CARD-1] | R | CARD-TF 2: 4.1 |
| | Modality Procedure Step Completed [RAD-7] | R | RAD-TF 2: 4.7 |
| | Modality Images/Evidence Stored [CARD-2] | R | CARD-TF 2: 4.2 |
| | Storage Commitment [CARD-3] | R | CARD-TF 2: 4.3 |
| Image Manager/ Image Archive | Procedure Scheduled [RAD-4] | R | RAD-TF 2: 4.4 |
| | Modality Procedure Step In Progress [CARD-1] | R | CARD-TF 2: 4.1 |
| | Modality Procedure Step Completed [RAD-7] | R | RAD-TF 2: 4.7 |
| | Modality Images/Evidence Stored [CARD-2] | R | CARD-TF 2: 4.2 |
| | Storage Commitment [CARD-3] | R | CARD-TF 2: 4.3 |
| | Patient Update [RAD-12] | R | RAD-TF 2: 4.12 |
| | Procedure Updated [RAD-13] | R | RAD-TF 2: 4.13 |
| | Query Images [RAD-14] | R | RAD-TF 2: 4.14 |
| | Retrieve Images/Evidence [CARD-4] | R | CARD-TF 2: 4.4 |
| | Instance Availability Notification [RAD-49] | O | RAD-TF 3: 4.49 |

| Actors | Transactions | Optionality | Section |
|---|---|---|---|
| Performed Procedure Step Manager | Modality Procedure Step In Progress [CARD-1] | R | CARD-TF 2: 4.1 |
| | Modality Procedure Step Completed [RAD-7] | R | RAD-TF 2: 4.7 |
| Image Display | Query Images [RAD-14] | R | RAD-TF 2: 4.14 |
| | Retrieve Images/Evidence [CARD-4] | R | CARD-TF 2: 4.4 |
| Evidence Creator | Modality Procedure Step In Progress [CARD-1] | R | CARD-TF 2: 4.1 |
| | Modality Procedure Step Completed [RAD-7] | R | RAD-TF 2: 4.7 |
| | Modality Images/Evidence Stored [CARD-2] | R | CARD-TF 2: 4.2 |
| | Storage Commitment [CARD-3] | R | CARD-TF 2: 4.3 |
| Report Creator | (See Text) | | |

Refer to Table 2-1 for other profiles that may be pre-requisites for this profile.

If a Report Creator wishes to participate in this profile, it does not have to support any transactions directly, however it is required to be grouped either with an Acquisition Modality, or with an Image Display in order to be able to Query/Retrieve the images, waveforms, and evidence documents. The Report Creator is expected to be able to transfer some contents of the created or retrieved objects into the reports it creates, and to send those reports in accordance with another Profile.

Note: See, e.g., Report Creator in the DRPT Profile.

## 8.2 Stress Workflow Integration Profile Options

Many Actors have Options defined in order to accommodate variations in use across domains or implementations. Options that may be selected for this Integration Profile are listed in the table 8.2-1 along with the Actors to which they apply. Certain of these Options are required for implementation by actors in this Profile (although they may be truly optional in other Profiles).

**Table 3.2-1: Stress Workflow - Actors and Options**

| Actor | Option Name | Optionality | Vol & Section |
|---|---|---|---|
| ADT Patient Registration | *No options defined* | - | - |
| Order Placer | *No options defined* | - | - |
| Department System Scheduler/Order Filler | Multi-modality Procedure Update | R | CARD-TF 2: 4.1 |
| | PPS Exception Management | O | RAD-TF 2: 4.7 |
| | Availability of PPS-Referenced Instances | O | RAD-TF 3: 4.49 |
| Acquisition Modality | Patient Based Worklist Query | O | RAD-TF 2: 4.5 |
| | Broad Worklist Query | R (see note 1) | RAD-TF 2: 4.5 |

| Actor | Option Name | Optionality | Vol & Section |
|---|---|---|---|
| | PPS Exception Management | O | RAD-TF 2: 4.7 |
| | Stress ECG | R (see note 2) | CARD-TF 2: 4.2 |
| | Stress Echo | R (see note 2) | CARD-TF 2: 4.2 |
| | Nuclear Medicine (see note 3) | R (see note 2) | RAD-TF 2: 4.8 |
| Image Manager/ Image Archive | PPS Exception Management | O | RAD-TF 2: 4.7 |
| | Intermittently Connected Modality | R | CARD-TF 2: 4.3 |
| | Stress ECG | R | CARD-TF 2: 4.2 |
| | Echocardiography | R | CARD-TF 2: 4.2 |
| | Nuclear Medicine (see note 3) | R | RAD-TF 2: 4.8 |
| | Availability of PPS-Referenced Instances | O | RAD-TF 3: 4.49 |
| Image Display | Stress ECG | R | CARD-TF 2: 4.4 |
| | Stress Echo | R | CARD-TF 2: 4.2 |
| | Cardiac NM (see notes 3, 4) | R | RAD-TF 2: 4.16 |
| Performed Procedure Step Manager | *No options defined* | - | - |
| Evidence Creator | *No options defined* | - | - |
| Report Creator | *No options defined* | - | - |

Note 1: The Broad Worklist Query option facilitates effective workflow in the multimodality environment.

Note 2: An Acquisition Modality shall support one of the options Stress ECG, Stress Echo, or Nuclear Medicine.

Note 3: Nuclear Medicine (NM) is not formally an option, but is rather a separate IHE Profile. The Image Manager/Image Archive and the Image Display must support the NM Profile.

Note 4: The Image Display shall support the Cardiac NM Option of the NM Profile.

## 8.3 Stress Testing Scheduled Process Flow

The process and information flow for Stress Test procedures generally follows the same flow as the Cath Scheduled Process Flow (see section 3.3).

## 8.4 Stress Testing Workflow Use Cases

Stress tests are performed to challenge the patient's cardiovascular system in a controlled stress-inducing environment.

A stress test is ordered by a physician, either inside the performing institution, or by a referral from outside the institution. The test is scheduled for the patient, transportation is arranged if the patient is an inpatient, equipment is scheduled, radiopharmaceuticals are ordered if the stress test is included with nuclear imaging, a room is reserved for the test, and personnel are scheduled. The

test is performed by a physician or trained professional (such as a nurse, physician's assistant, or trained exercise technician).

In order to stress the patient, a stress test commonly uses an exercise device such as a treadmill or bicycle ergometer. Other types of stress agents are pharmacologic and metabolic. Regardless of the stress method, the Stress Monitor measures the stress study time, obtains electrocardiograms at discrete intervals, and reports out the performance of the patient's cardiovascular activity at each stage of work. The end point of the study is determined by a physician, or trained allied health individual, and then interpreted.

Stress testing is performed alone, or in conjunction with an imaging protocol such as a thallium nuclear cardiology study, or stress echocardiography. The management of the test must take into account all potential modalities.

### 8.4.1 Use Case S1: Cardiac Stress Test, ECG Only

A cardiac stress test is performed based on a prescribed exercise or pharmacological stress protocol. This protocol is divided into stages of stress, where typical stages are Resting, Baseline, Stage 1, Stage 2,…, Recovery. The patient is subjected to increasing levels of stress for each stage while the Stress Monitor collects ECG waveforms, patient physiological parameters (stress symptoms, heart rate, blood pressure), and equipment settings (speed, elevation, duration). A typical stress examination goes through progressive stages until a clinical end-point is reached, such as achieving a pre-determined heart rate or emergence of symptoms preventing the patient from continuing (arrhythmia, hypotension, angina, fatigue, etc.). A test is typically be completed even though the protocol did not complete, i.e. a fewer number of planned stages were completed. Once the test is complete, it is interpreted by a physician, and the results are reported.

The following is a typical workflow for a cardiac stress test:

1. A Stress Test order is placed.
2. The Stress Monitor equipment is scheduled, and the stress protocol is selected.
3. The patient arrives for the test.
4. The patient demographics and order information is loaded into the Stress Monitor.
5. The stress protocol is confirmed or changed as determined by the person performing the test.
6. The patient is prepared for the stress test:
    a. The patient's skin is prepared for the ECG electrodes, and the electrodes are attached to the skin.
    b. If blood pressure will be monitored, the cuff is placed on the patient.
7. The patient is placed in a supine position and Resting ECG waveforms are collected.

 

8. If using an exercise stress protocol, the patient gets on the exercise equipment at rest, and Baseline ECG waveforms are collected.
9. The stress protocol is started and ECG waveforms are collected as the protocol is run through its stages of increasing stress. For an exercise protocol, this is typically done by increasing the elevation and/or speed of a treadmill or increasing the resistance of an ergometer. And for a pharmacologic protocol, this is done by periodic drug injections.
10. The test is terminated when the patient reaches "maximum stress" or exhibits other adverse symptoms.
11. The Recovery ECG waveforms are collected.
12. The stress test is reviewed by a physician; either on the Stress Monitor, or on a reviewing workstation. In the latter case, the stress waveforms and other data must be sent to this workstation from the Stress Monitor.

### 8.4.2 Use Case S2: Cardiac Stress Test with Imaging

It is estimated that 80+ % of stress tests are done in conjunction with an Echo exam in the acute care market in the United States. Therefore, there exists a clinical need to combine clinical information from Stress Monitors and Imaging Modalities. In these cases the medical devices involved in the exams shall be synchronized to a common time source. The synchronization is required to correctly time align the Stress Monitor data with the Imaging data.

The following is a typical workflow for a stress test combined with imaging:

1. A Stress Test with imaging order is placed.
2. Stress Monitor and Imaging equipment are scheduled, and the stress protocol is selected.
3. The patient arrives for the test.
4. The patient demographics and order information is loaded into the Stress Monitor and Imaging equipment.
5. The stress protocol is confirmed or changed as determined by the person performing the test.
6. The ECG waveform analog output from the Stress Monitor is connected to the Imaging machine. This analog output provides a cardiac gating signal for the collection of cardiac images.
7. The patient is prepared for the test:
    a. The patient's skin is prepared for the ECG electrodes, and the electrodes are attached to the skin.
    b. If blood pressure will be monitored, the cuff is placed on the patient.

 

8. The patient is placed in a supine position and Resting ECG waveforms are collected.
9. Resting, pre-stress images are collected.
10. If using an exercise stress protocol, the patient gets on the exercise equipment at rest, and Baseline ECG waveforms are collected.
11. The stress protocol is started and ECG waveforms are collected as the protocol is run through its stages of increasing stress. For an exercise protocol, this is typically done by increasing the elevation and/or speed of a treadmill or increasing the resistance of an ergometer. And for a pharmacologic protocol, this is done by periodic drug injections.
12. Mid-stress images are collected as needed during a pharmacologic protocol.
13. The test is terminated when "maximum stress" is achieved the patient exhibits other adverse symptoms.
14. The Stress Monitor enters the Recovery stage and starts collecting Recovery ECG waveforms.
15. "Peak stress" images are collected.
16. The stress test is stopped. The Stress Monitor and Imaging machine stop collecting data.
17. The data collected from the Stress Monitor and Imaging machine are reviewed and a final report is created.

# Additions to IHE Cardiology Technical Framework Volume 2

*Add to Section 4.2*

## 4.2 Modality Images/Evidence Stored [CARD-2]

...

### 4.2.6 Stress ECG Option

Image Archives supporting the STRESS ECG option are required to support all of the SOP classes listed in Table 4.2-1 below.

**Table 4.2-10. Stress ECG SOP Classes**

| SOP Class UID | SOP Class Name |
|---|---|
| 1.2.840.10008.5.1.4.1.1.9.1.1 | 12-Lead ECG Waveform Storage |
| 1.2.840.10008.5.1.4.1.1.9.1.2 | General ECG Waveform Storage |
| 1.2.840.10008.5.1.4.1.1.88.22 | Enhanced SR |
| 1.2.840.10008.5.1.4.1.1.88.33 | Comprehensive SR |
| 1.2.840.10008.5.1.4.1.1.88.40 | Procedure Log |
| 1.2.840.10008.5.1.4.1.1.104.1 | Encapsulated PDF |

Acquisition Modality actors supporting the STRESS ECG option are required to support a number of attributes in ECG Waveform objects created for a stress procedure as described in Table 4.2-11. Many of these requirements build on attributes which are Type 2 or Type 3 in DICOM (such attributes are indicated with R+).

**Table 4.2-11. Attributes That Convey Staged Protocol Related Information**

| Attribute Name | Tag | Requirement |
|---|---|---|
| Performed Procedure Step Description | (0040,0254) | R+ |
| Protocol Name | (0018,1030) | R+ |
| Performed Protocol Code Sequence | (0040,0260) | R+ |
| Acquisition Context Sequence | (0040,0555) | R+ |

The Performed Protocol Code Sequence for stress test procedures shall use codes drawn from the subset of DICOM Context Group 3261 shown in Table 4.2-12.

**Table 4.2-12. ECG Stress Protocol Codes**

| Coding Scheme Designator (0008,0102) | Code Value (0008,0100) | Code Meaning (0008,0104) |
|---|---|---|
| SRT | P2-7131C | Balke protocol |
| SRT | P2-7131A | Bruce protocol |
| SRT | P2-7131D | Ellestad protocol |
| SRT | P2-7131B | Modified Bruce protocol |
| SRT | P2-713A1 | Modified Naughton protocol |
| SRT | P2-713A0 | Naughton protocol |
| SRT | P2-7131F | Pepper protocol |
| SRT | P2-7131E | Ramp protocol |
| SRT | P2-31102 | Bicycle Ergometer Stress Test protocol |
| 99IHE | PHARMSTRESS | Pharmacologic Stress protocol |
| 99IHE | PERSANTINE | Persantine Stress protocol |
| 99IHE | ADENOSINE | Adenosine Stress protocol |
| 99IHE | DOBUTAMINE | Dobutamine Stress protocol |

*Adapted from DICOM PS3.16-2004*

The Acquisition Context Sequence shall include at least the two content items shown in Table 4.2-13, drawn from DICOM Template 3401, and use the codes from DICOM Context Group 3262 shown in Table 4.2-14.

**Table 4.2-13. Acquisition Context Items**

| Value Type | Concept Code | Value |
|---|---|---|
| CODE | (109054, DCM, ”Patient State”) | See Table 4.2-14 |
| NUM | (109055, DCM, ”Protocol Stage”) | Numeric Value, Units of Measurement is (“{stage}”, UCUM, “stage”) |

*Adapted from DICOM PS3.16-2004*

**Table 4.2-14. Patient State Codes**

| Coding Scheme Designator (0008,0102) | Code Value (0008,0100) | Code Meaning (0008,0104) |
|---|---|---|
| SRT | F-01604 | Resting state |
| SRT | F-01602 | Baseline state |
| SRT | F-01606 | Exercise state |
| SRT | F-01608 | Post-exercise state |

*Adapted from DICOM PS3.16-2004*

*Add to Section 4.4*

## 4.4 Retrieve Images/Evidence [CARD-4]

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### 4.4.4 Stress ECG Option

Image Display actors supporting the STRESS ECG option are required to support all of the SOP classes listed in Table 4.4-8 below.

**Table 4.4-8. Stress ECG SOP Classes**

| SOP Class UID | SOP Class Name |
|---|---|
| 1.2.840.10008.5.1.4.1.1.9.1.1 | 12-Lead ECG Waveform Storage |
| 1.2.840.10008.5.1.4.1.1.9.1.2 | General ECG Waveform Storage |
| 1.2.840.10008.5.1.4.1.1.88.22 | Enhanced SR |
| 1.2.840.10008.5.1.4.1.1.88.33 | Comprehensive SR |
| 1.2.840.10008.5.1.4.1.1.88.40 | Procedure Log |
| 1.2.840.10008.5.1.4.1.1.104.1 | Encapsulated PDF |

#### 4.4.4.1 Expected Actions

The Image Display actor is expected to render the ECG waveforms in a clinically relevant way. The actor is expected to be able to handle the display of representative beats and rhythm waveforms. Stress ECGs are typically not more than 15 leads. Full disclosure ECG waveforms from the entire test are typically less than 30 minutes. Each waveform must be labeled with the lead name. The following information about the waveforms shall be displayed:

- Voltage scale

- Time scale
- Frequency content
- Acquisition time
- Originality -- e.g., original (rhythm) or derived (representative beat)
- Protocol name, protocol stage, and patient state.

The Image Display actor shall support the display of DICOM Encapsulated PDF and DICOM SR SOP Instances.

Note: An Image Display that supports a DICOM SR SOP Class is required (by the DICOM Standard) to unambiguously render all legal SOP Instances within that SOP Class, regardless of the Template used to create it. See DICOM PS3.4 Annex O.

*Add new Appendix*

# Appendix X – Stress Test Protocol and Stage Identification

For various historical and clinical reasons, the manner in which stress test protocols and protocol stages are identified differs across the modality information object definitions. This appendix elucidates the requirements for such identification.

## X.1 Procedure

In stress testing, the selection of the protocol is first constrained by the selection of the type of stress test procedure, i.e., the modality or modalities to be used (stress ECG alone, ECG plus echo or nuclear imaging, or imaging alone), and the selection of the stress induction method (exercise or pharmacological). This top level procedure type selection must be done at test scheduling time in order to marshal the necessary resources for the test, and is conveyed in the Requested Procedure Code Sequence.

## X.2 Protocol

Within the Requested Procedure, the specific protocol is selected. Typically this is done at the acquisition equipment when the test is set up. However, it can also be specified (or recommended) during scheduling. In the DICOM information model, this protocol is a modality-dependent construct associated with the scheduled and performed procedure steps.

As a modality-dependent construct, there is no need for the protocol to be identical between the ECG and imaging modalities. In fact, the ECG modality may have a deeper understanding of the range of such protocols than the imaging modalities. The clinical requirement is for each modality to encode its acquired data with sufficient information about the protocol so as to be able to interpret the data.

When the protocol is selected during scheduling, its coded representation is passed to the modalities in the Scheduled Protocol Code Sequence attribute. The protocol actually used by the modality (which may differ from the scheduled protocol) is reported in the Performed Protocol Code Sequence attribute of the composite object and the Modality Performed Procedure Step object. The required values for this attribute are enumerated in table 4.2-3 for Echo and in table 4.2-12 for ECG. It is recommended that NM use the values in 4.2-12.

Note that the ECG Acquisition Context Template 3401 used in Stress ECG Waveform objects allows encoding of the protocol in the Acquisition Context Sequence attribute, but that use is deprecated by IHE in favor of the Performed Protocol Code Sequence attribute.

## X.3 Stage

Stress protocols typically have a series of stages. These stages typically increase the level of stress. Each stage is defined by the protocol and is identified by a number. For example, the Bruce protocol has 7 stages of work identified as stages 1, 2, 3, 4, 5, 6 and 7. Stage 1 has a treadmill speed of 1.7 mph with a 10% grade and stage 7 has a speed of 6.0 mph with a 22% grade. These protocol stage identifiers are recorded with the ECG waveforms in the Acquisition Context Sequence.

The state of the patient relative to the overall test regimen is recorded in the Acquisition Context Sequence of ECG and NM objects as "Patient State". These coded states are enumerated in table 4.2-14.

The echocardiography modality also records the patient state using the attribute Stage Code Sequence. These codes are enumerated in table 4.2-4 and convey similar concepts to those in table 4.2-14. Echocardiography similarly identifies for grouping purposes all images acquired in a particular patient state using a numeric value denoted "Stage Number". This "Stage Number" should **not** be confused with the protocol stage number; it is a sequencing number meaningful only to the echo modality.

## X.4 Attribute Summary

A summary of the attributes used for protocol and stage identification is show in Table X-1.

**Table X-1. Stress Protocol and Stage Concepts and Attributes**

| Concept | Modality Worklist | Echo | ECG | NM |
|---|---|---|---|---|
| Requested Procedure | Requested Procedure Code Sequence (0032,1064) | Procedure Code Sequence (0008,1032) | Procedure Code Sequence (0008,1032) | Procedure Code Sequence (0008,1032) |
| Protocol | Scheduled Protocol Code Sequence (0040,0008) | Performed Protocol Code Sequence (0040,0260) CID 12001* | Performed Protocol Code Sequence (0040,0260) CID 3261 | Performed Protocol Code Sequence (0040,0260) CID 3261** |
| Protocol Stage Number | | | Acquisition Context Sequence (0040,0555) >(109055, DCM, "Protocol Stage") | |
| Patient State | | Stage Number (0008,2122) Stage Code Sequence (0040,000A) CID 12002* | Acquisition Context Sequence (0040,0555) >(109054, DCM, "Patient State") CID 3262 | Acquisition Context Sequence (0040,0555) >(109054, DCM, "Patient State") CID 3101 |

* Concepts in these Context Groups apparently do not exist in SNOMED (Doh!)

** Recommended.

 