ATC-ITC Informatics Infrastructure

Walter R. Bosch, Joe Deasy, and James A. Purdy

Acknowledgments

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Providing support in quality assurance and data management for radiation therapy clinical trials

ATC Support of Cooperative Groups
(Electronic Submission, Credentialing, Dosimetry, QA)

QuASA^{2}R

Participating Institutions

MAX

Digital Data Flow .... Credentialing & QA
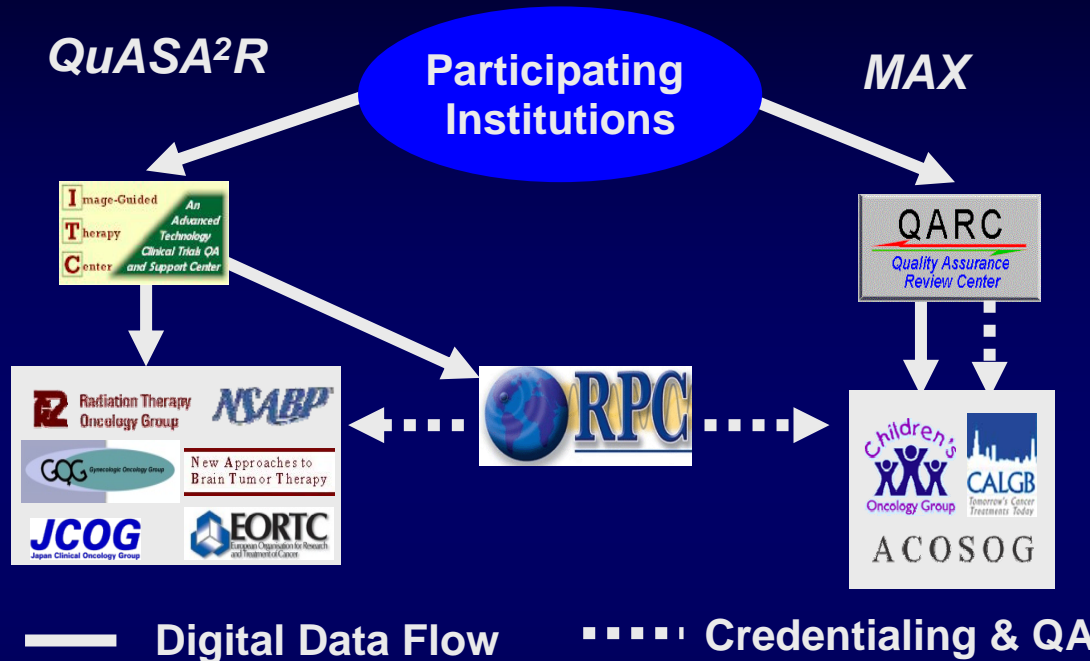
- ATC effort has provided all U.S. Cooperative Groups the ability to submit case digital data (images /volumetric TP data to either ITC or QARC for QA and outcomes analysis.

- 599 institutions submit to ITC: (Supports 15 closed protocols (analysis) and 21 active protocols

- 20 commercial TPS (11 vendors) ATC compliant

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ATC QuASA²R (Quality Assurance Submission, Archive, Analysis, and Review) System
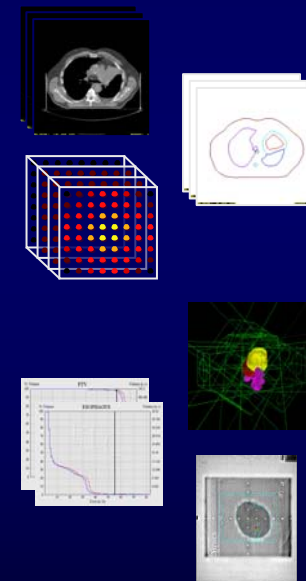
- Development has been guided by experience in supporting the collection of volumetric treatment planning data from commercial treatment planning systems.
  - Investment in the interfaces (RTOG Data Exchange Format and the DICOM Standard)
  - Support for TP vendor data export
- System is built to support real-world QA process.
- System has maintained continuous support for the collection and QA review of nearly 8000 protocol case data sets.
- This effort has enabled the creation of a large archive of treatment planning data, linked to clinical outcomes, for these cases for later data mining.

QuASA²R – *Current Components and Data Flow*

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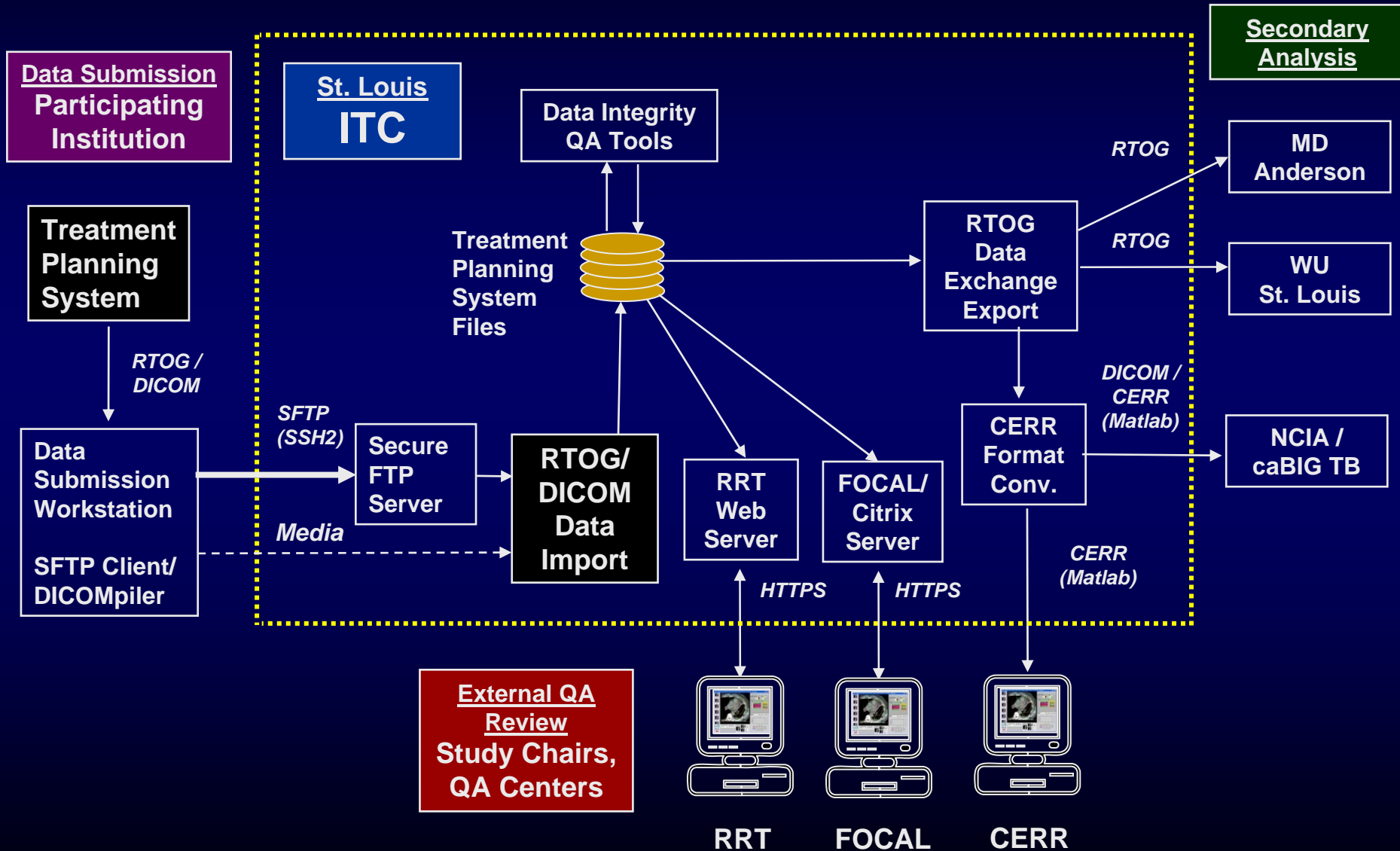
Protocol Case Submissions

- As of September 12, 2008: <u>7756</u> Complete, Protocol-Case, Volumetric Digital Data Sets Submitted Over 14+ Year Period using the ATC QuASA^{2}R System

Annual Advanced-Technology Protocol Case Accruals

Legend:
- Others (cyan)
- Others Phase III (purple)
- 0413 (magenta)
- 0126 (yellow)
- 9406 (green)
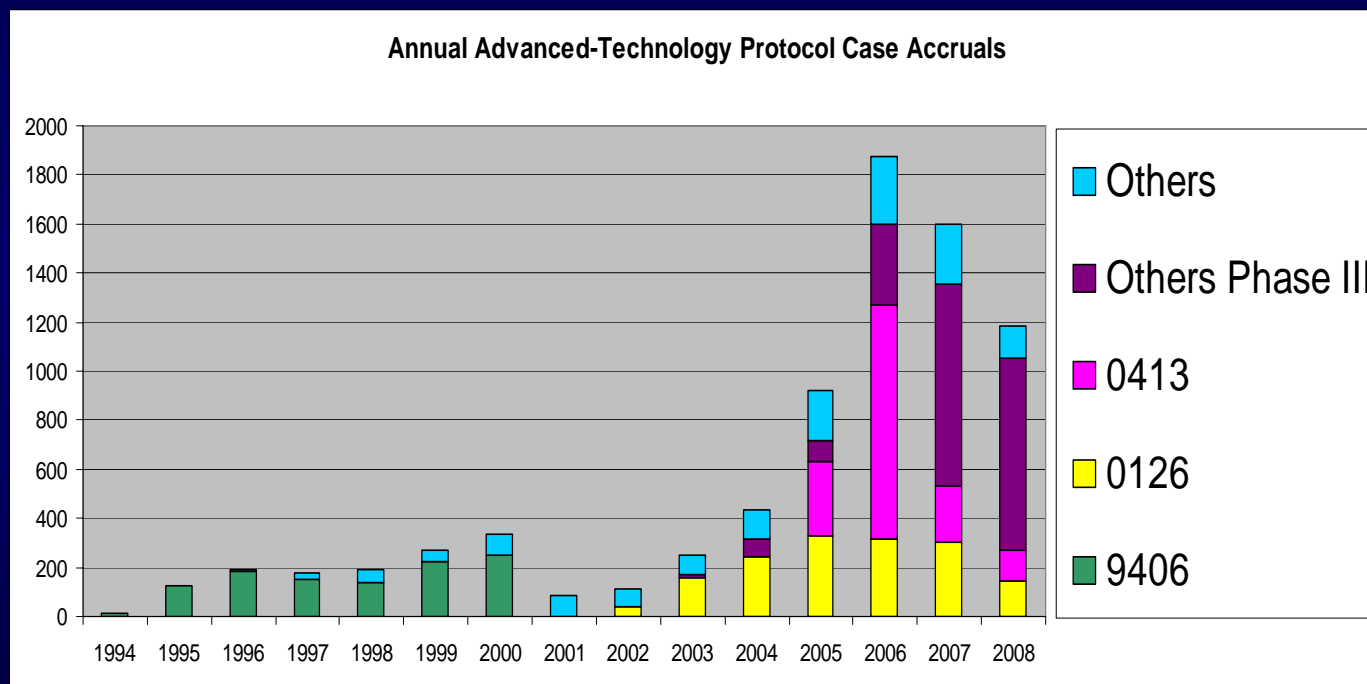
- 11 commercial TPS vendors (20 TPSs) have implemented ATC compliant export capability.
- 599 institutions able to submit digital RT data

ATC(ITC) Case QA Review Process

- ITC is responsible for **Digital Data Integrity QA (DDIQA)** review which includes review for :
  - completeness of protocol required elements
  - format of data, spatial registration, dose scaling,
  - possible data corruption; and
  - recalculation of all Dose Volume Histograms (DVHs).
- Coop. Group is responsible for **Protocol Compliance QA (PCQA)** review which includes review of :
  - TVs and OARs contours compliance
  - protocol dose prescription and dose heterogeneity compliance by cooperative group specific reviewer(s) such as the Protocol Study Chair (SC) using QuASA^{2}R's web-based *Remote Review Tool (RRT)*.

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QuASA²R – *Data Submission*

- Data Representation
  - RTOG Data Exchange (legacy) – adapted and maintained by ITC for RTOG trials data submission
  - DICOM RT Objects
    - ITC participated in developing DICOM RT Objects
    - ATC DICOM Conformance Statement
    - First DICOM submissions to ITC in 2003
- Data Transport
  - Secure FTP
  - CD Media
  - caGrid (caBIG)

Treatment Planning & Verification
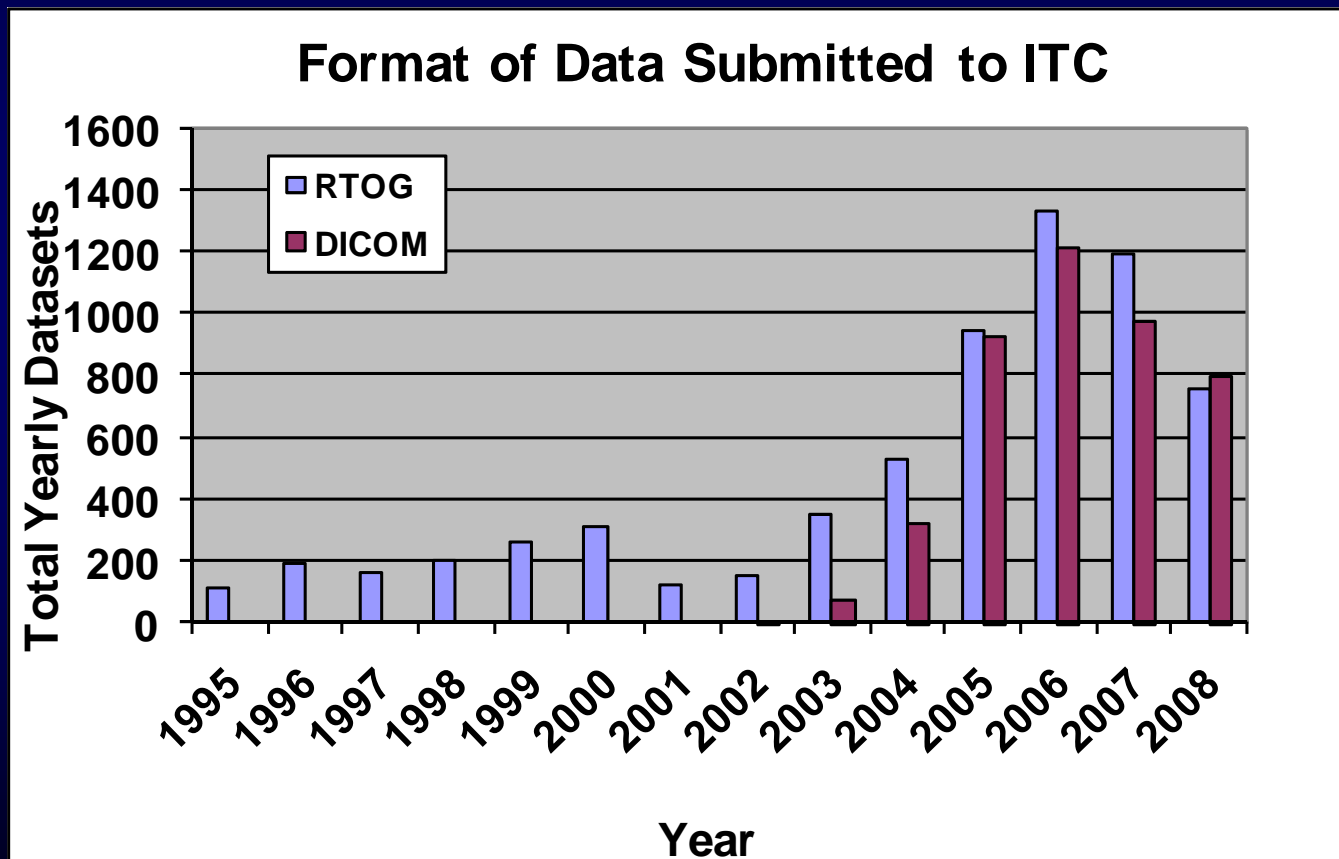
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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Data Submission*

- Nearly 50% of submissions now use DICOM

Treatment Planning & Verification

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Data Submission

⬇

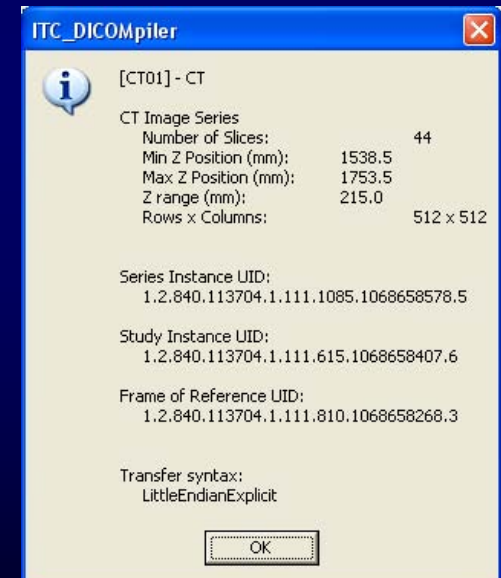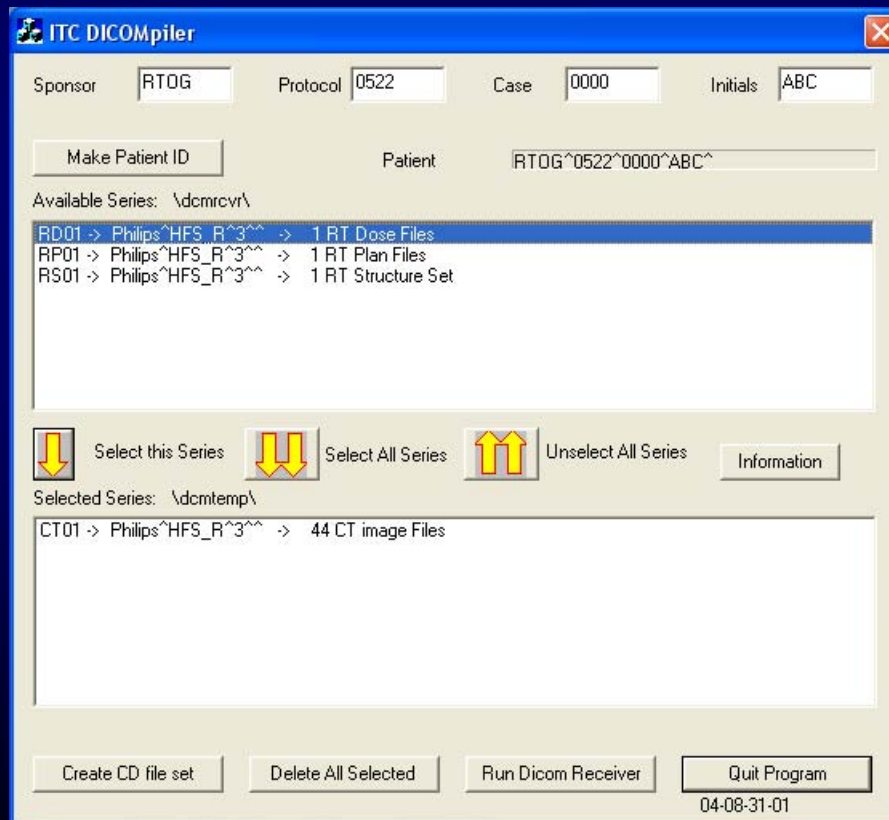**Data Integrity QA**

⬇

Protocol Compliance Review

⬇

Outcomes Analysis

Format of Data Submitted to ITC

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Data Selection and Anonymization

- **ITC DICOMpiler** (Windows) software
  - DICOM Receiver (Storage SCP), DICOM Series Selector, Anonymizer, and Part 10 Media Fileset Creator
  - Anonymized filesets can be sent by SFTP or on CD.

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Providing support in quality assurance and data management for radiation therapy clinical trials

QuASA²R – *Data Integrity QA (DDIQA)*

- Data Integrity QA Prior to Review for Protocol Compliance
  - Experience shows approximately 25% of data sets received require some intervention to be reviewable.
  - Data QA Concerns
    - Completeness
      - Are required objects present and interpretable?
    - Identification
      - Are case, plan, structure IDs consistent?
    - Consistency
      - Are images, structures, doses spatially registered?
      - Are doses properly scaled?
      - Are DVHs calculated in a consistent manner?

Treatment Planning & Verification

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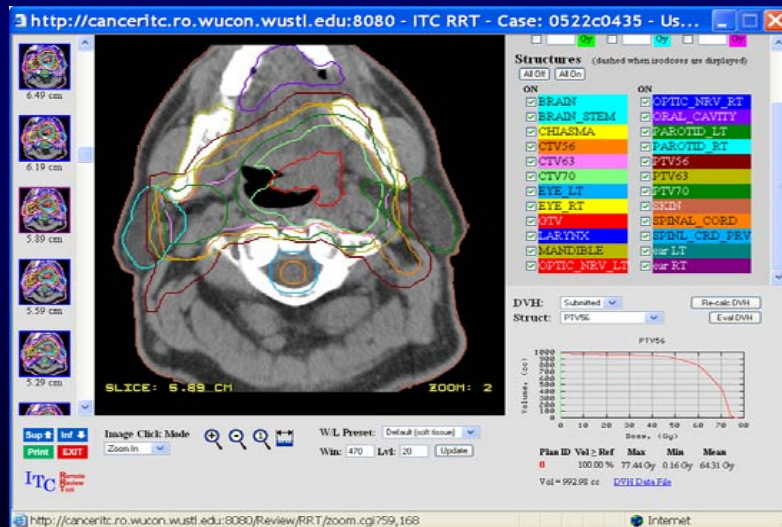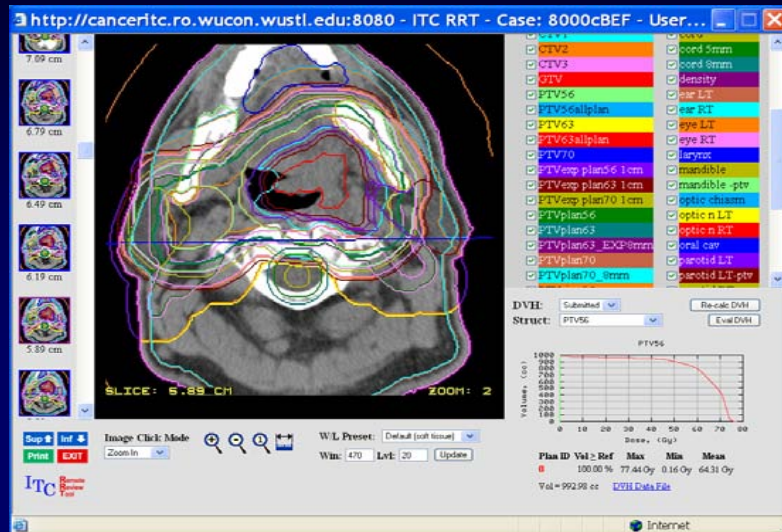**Data Submission**

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Data Integrity QA (DDIQA)*

- A H&N IMRT case before (upper) and after (lower) it is prepared for review by ITC personnel.
- Many contours used for plan optimization (extraneous in the review process) are removed.
- Protocol-required structures are re-named to standard names.
- PI physician reviewer sees only the anatomical structures needed to evaluate protocol compliance.
- Before DDIQA, this case had 51 structures. After DDIQA it had only 24 structures all of which represent protocol-required anatomy and targets.

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Data Integrity QA (DDIQA)*

Rename Structures – (cancer)

Patient ID: 0522cdr001   Name: 0522cdr001

For each patient contour
  (1) select existing structure name from left hand list.
  (2) select (new) standard structure name to from right hand list.

Rename   Select structures: 0522

Structure Names	Standard Structures
01 GTV	BRAC_PLX
02 * GTV2cm	CTV56
03 * LtElecNodalCTV	CTV63
04 * RtElecNodalCTV	CTV70
05 CTV1	GTV
06 CTV2	LARYNX
07 PTV1	PAROTID_LT
08 PTV2	PAROTID_RT
09 * Cord	PTV56
10 * Brainstem	PTV63
11 * Brain	PTV70
12 PAROTID_LT	SKIN
13 PAROTID_RT	SPINAL_CORD
14 * Parotids	SPINL_CRD_PRV
15 LARYNX	

Save / Quit   Cancel

Add Plans – (cancer)

Patient ID: 0522c0023   Name: 0522c0023

Plan List
fx1hetero
fx2hetero
fx3hetero
fx4hetero
fx5hetero
fx6hetero
fx7hetero
totalhetero

Dose Status: fx2hetero: Doses Exist
Current Plan: fx2hetero
    Set Plan 1   Set Plan 2
Plan ID: fx1hetero   fx2hetero
Scale Factor: 1.00   1.00

New Plan Information
Plan ID: Description:

Quit Add Plans

- **Uniform structure names** permit comparison of DVHs among subjects enrolled on a clinical trial protocol.
- Submitted structure names often differ from standard names posted on the ATC website.
- Tool at left is used for renaming of structures to follow a uniform naming convention.

- Fraction group doses are submitted separately to maintain patient's fractionation scheme for later analysis.
- The tool at left is used to **sum fraction group doses** to compute dose volume statistics for the total dose delivered to the patient.

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Data Integrity QA (DDIQA)*

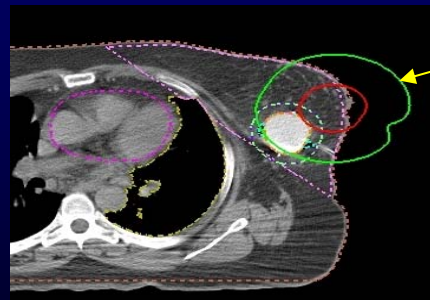- **DICOM Dose Grid Row/Column Pixel Spacing Attribute**
    - Pixel Spacing Value Order Clarification (CP626) added to the DICOM Standard in 2007:

        "It is not expected that this has ever … actually been misinterpreted, since practically all implementations affected the pixel spacing attributes use square pixels."
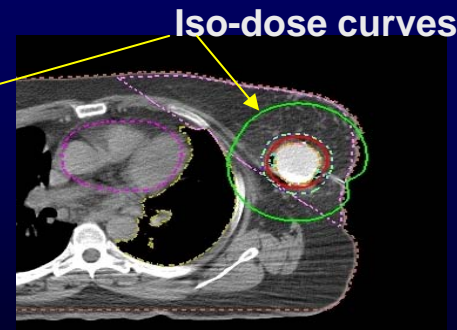
    - Dose grid pixels (in-plane) are *almost* always square
    - Non-square pixels seen in only two cases (of >2200 DICOM submissions) in four years

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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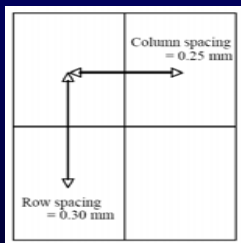
Outcomes Analysis

From DICOM PS 3.3–2007
Section 10.7.1.2

Column spacing = 0.25 mm

Row spacing = 0.30 mm

Iso-dose curves

Incorrect row/ column spacing

Correct row/ column spacing

QuASA²R – *Data Integrity QA (DDIQA)*

- Example of a spatial registration error due to incorrect DICOM implementation by the Vendor.
- The patient was planned Head First Prone, but the dose was exported as Head First Supine, causing a mis-registration of the dose relative to the patient anatomy.

- Rapid review case requiring PCQA review by the protocol PI before the patient could start treatment.
- Problem was identified (and corrected) by ITC personnel during DDIQA, so that the case could be reviewed in the time allotted for rapid reviews (3 business days).
- Extensive comparisons of the corrected data with screen captures provided by the institution were needed to assure correctness of the imported data.
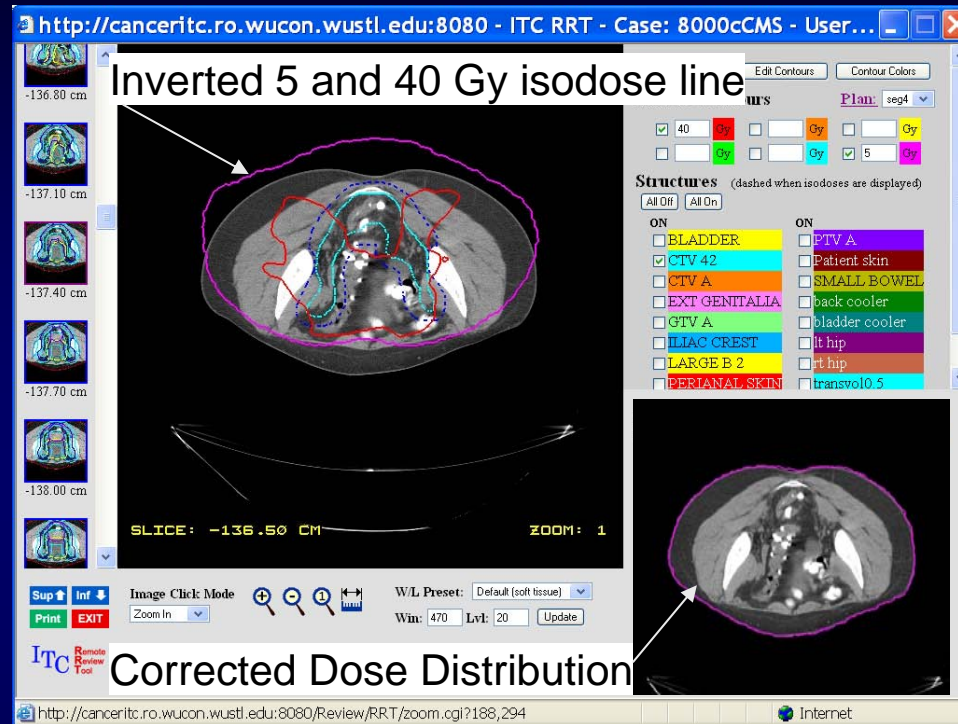
Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Data Integrity QA (DDIQA)*

- **Data Integrity QA Automation**
  - Procedures and tools developed by the ITC have made possible
    - the collection and Protocol Compliance evaluation of a large volume of data for advanced technology RT clinical trials and
    - the creation of a large archive of treatment planning data for these cases for later data mining.
  - A focused review of the data collected over the past two years shows that approximately 26% of the protocol case data and 29% of phantom data submitted requires human intervention in order to obtain complete, reviewable digital data.
  - The processing of digital data for the review of advanced technology clinical trials is <u>not a totally automated process</u> – need efficient tools.

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

- ## PCQA Review Tools – *Remote Review Tool (RRT)*
  - ### Web application for distributed case review
    - Intuitive user interface
    - Low bandwidth, low latency
    - Minimal configuration requirements

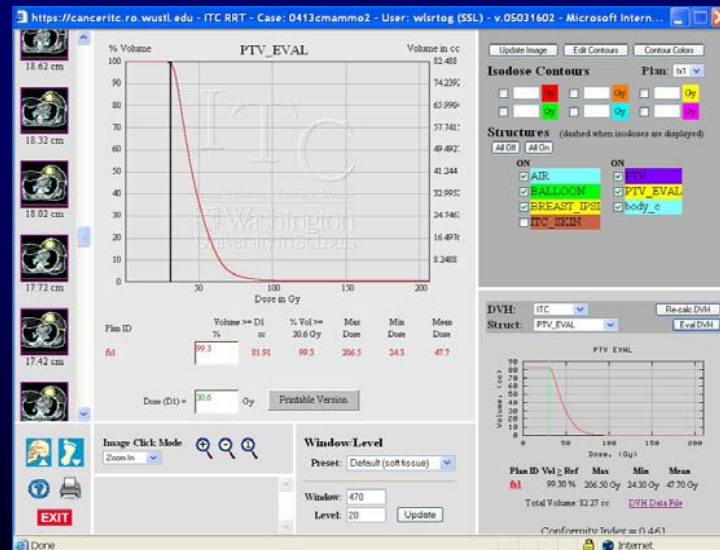**Treatment Planning & Verification**
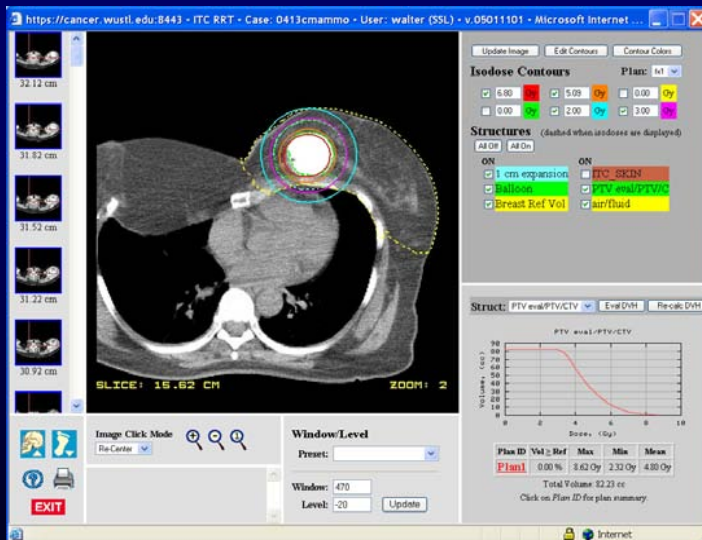
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Data Submission

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Data Integrity QA
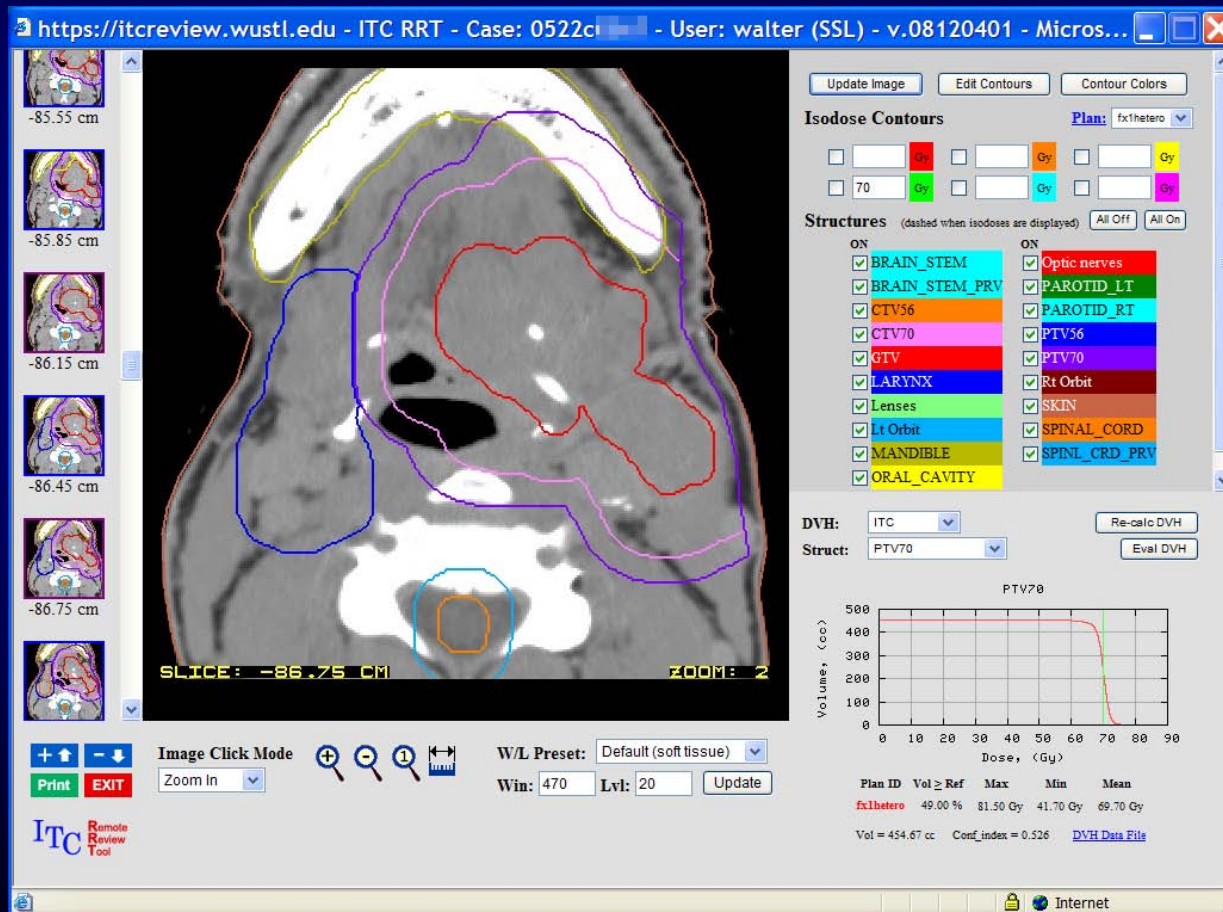
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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

1. Review Target Volume and Organ-at-Risk Delineation
   - Slice selection, window/level, zoom, re-center, contour on/off
   - Measurement tool, Contour editor

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

2. Review Dose Volume Statistics for TV coverage, OAR avoidance
   - Interactive Dose Volume Histogram display
   - DVH re-calculation of user-edited contours, structure combinations
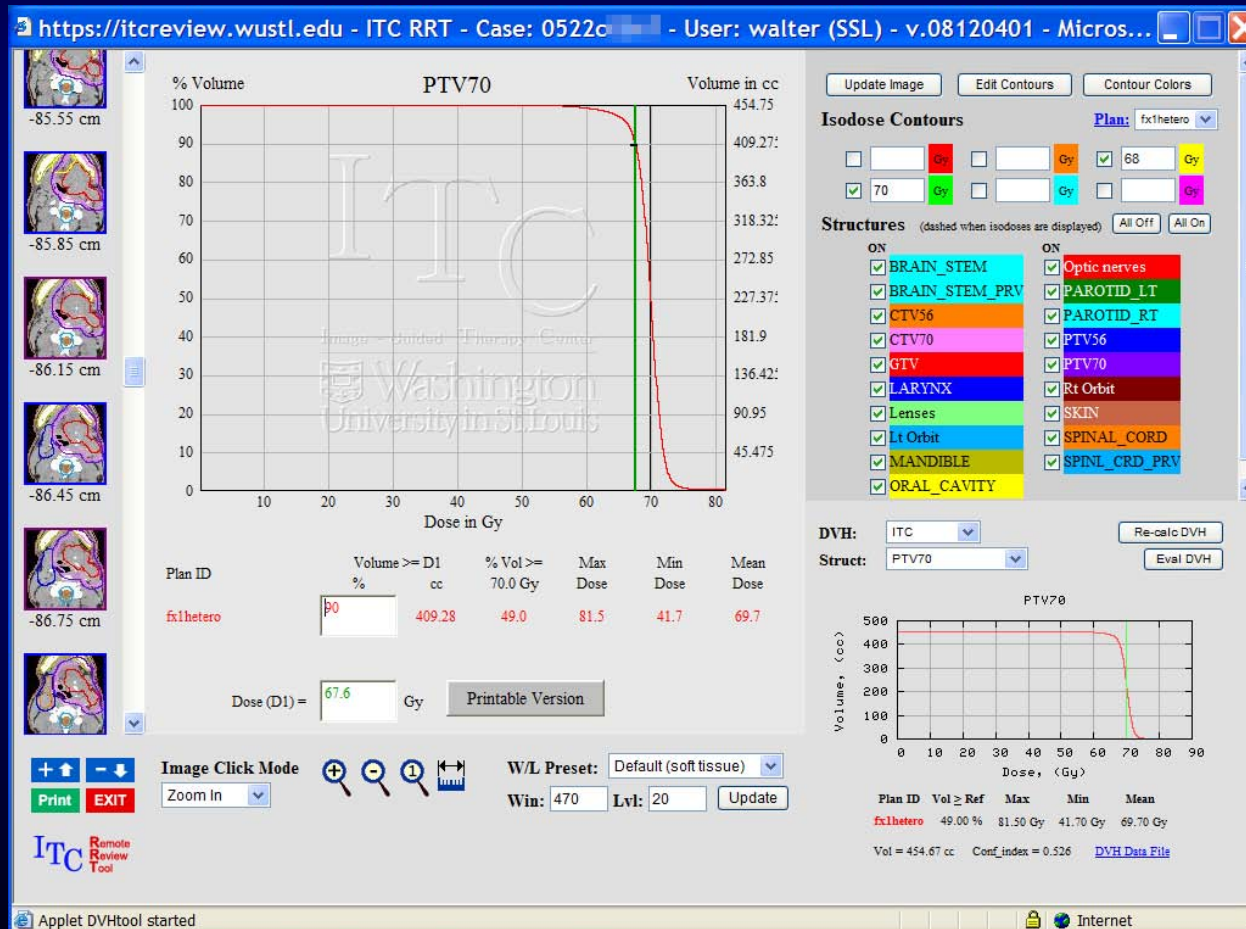

Treatment Planning & Verification

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Data Submission
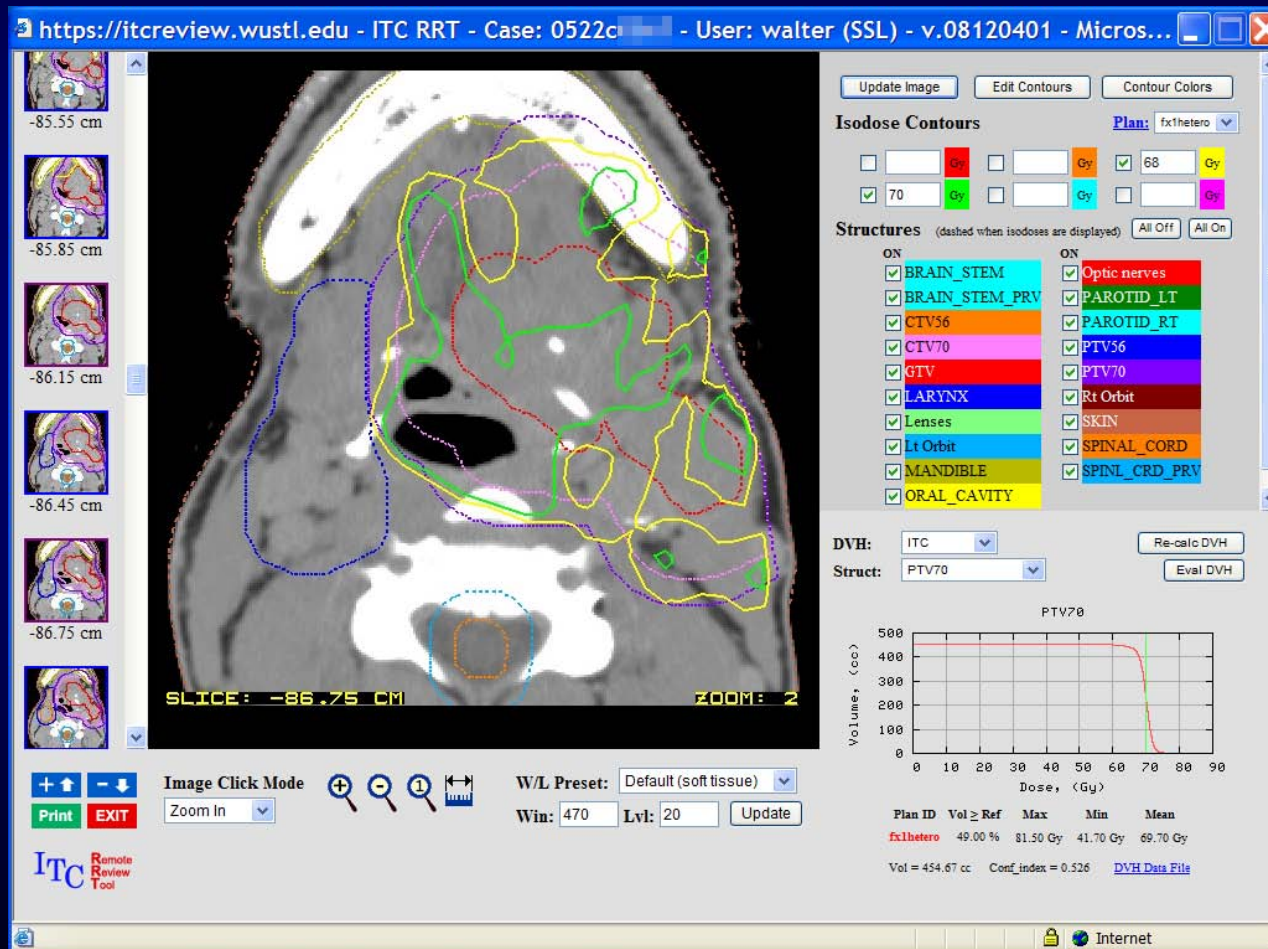
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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

3. Review iso-dose contours on CT images
   - Six user-selectable iso-dose levels
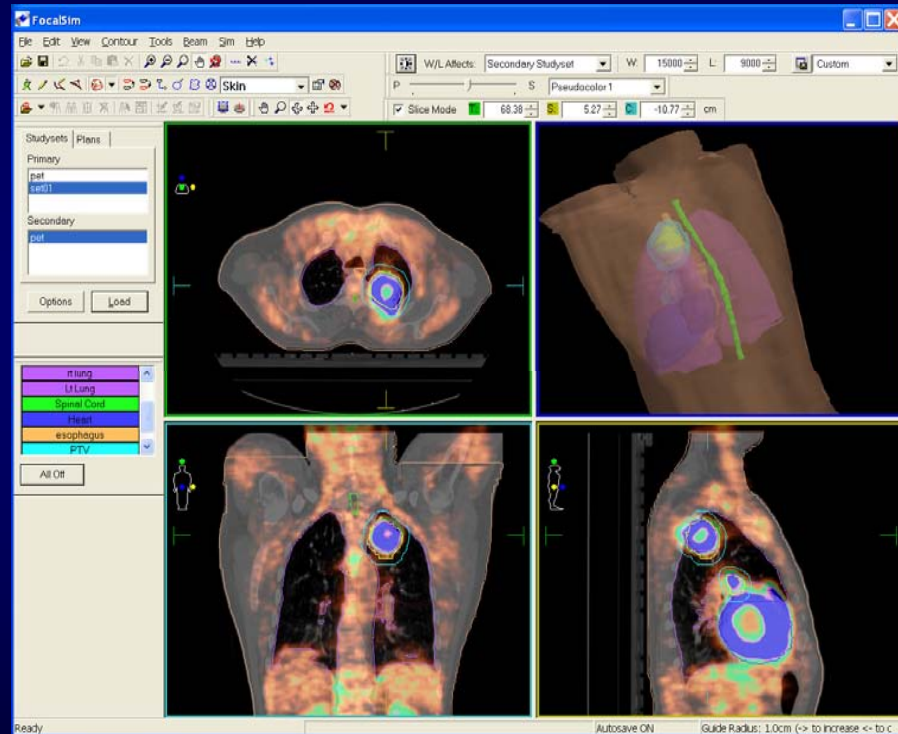

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

- PCQA Tools - *Local TP system (CMS Focal®)*
- PET Image Review for RTOG 0515

  - Institution submits PET DICOM Images and TP data to ITC using SFTP or media.
  - PET/CT image registration checked at ITC using FOCAL software.
  - TV contours drawn with and without PET are evaluated using FOCAL.
  - Labor intensive DDIQA

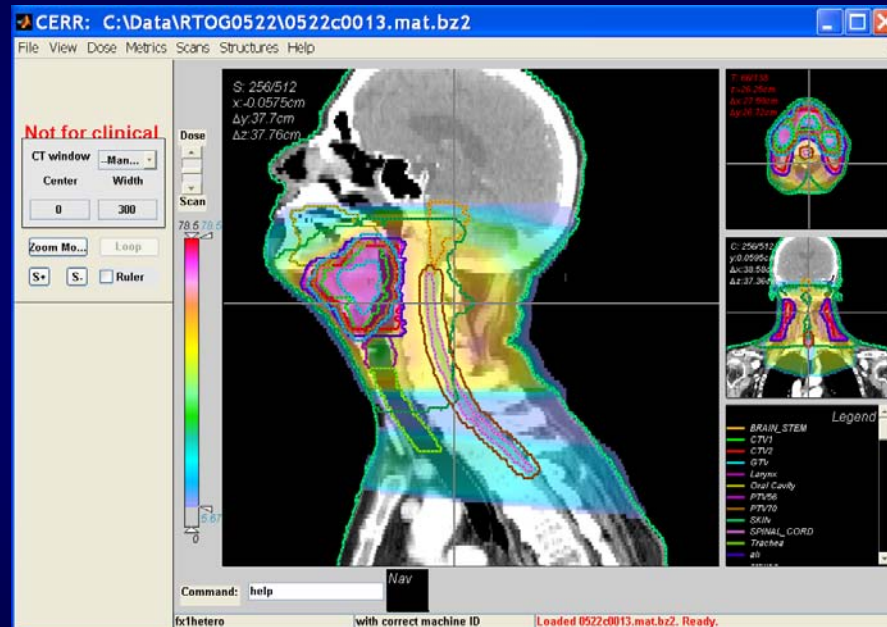**Treatment Planning & Verification**

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

- PCQA Tools - **C**omputational **E**nvironment *for **R**adiotherapy **R**esearch (CERR)*

- ITC uses CERR for
  - Data format conversion
    - RTOG/DICOM Import
    - DICOM Export
  - Contour editing
  - Image registration/ resampling
  - Film dosimetry QA
  - Image/plan review
    - Local
    - Webex
- CERR has been adopted by QARC
- ITC is working with Dr. Joe Deasy and colleagues to further develop CERR to meet ATC needs.

Treatment Planning & Verification
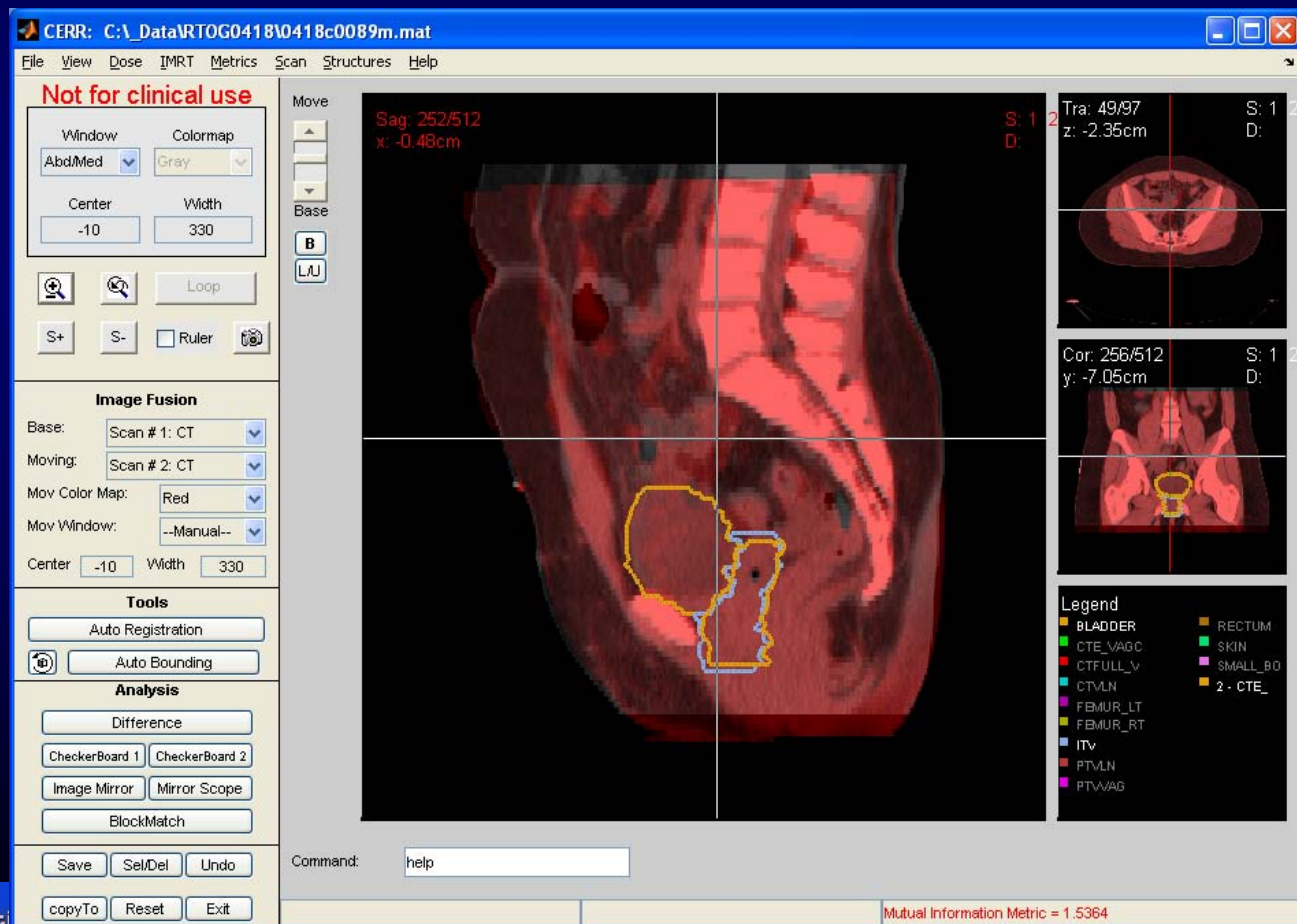
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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)* using CERR – Example: RTOG 0418

- Evaluation of ITV using registration of full-bladder (planning) CT and empty-bladder CT scans.

- Multi-planar display
  - Images
  - Structures
  - Dose
- Protocol Case QA using
  - CERR
  - WebEx

ATC QuASA²R (Quality Assurance Submission, Archive, Analysis, and Review) System Development

- Constraints
  - New imaging and treatment technologies, e.g., IGRT, ART, require new QA workflows, new tools.
  - Tools must support DDIQA as well as PCQA workflow
  - System must maintain continuous support for ongoing protocols
  - Development budget is limited
- Approach
  - Use modular approach to enable stepwise implementation, testing, and upgrades, while maintaining service to ongoing studies
  - Invest in the interfaces, i.e., data standards (DICOM, IHE-RO) and support for TP vendor data export
  - Use commercial "off-the-shelf" and open-source software wherever possible and focus custom software development efforts only on features not otherwise available.

QuASA²R – *Protocol Compliance QA (PCQA)*

- **Current Needs for Protocol Case QA Review Tools**
  - *Multi-Planar (T/S/C) Treatment Plan Review*
    - *OAR, TV delineation*
    - *Dose distribution*
  - *Multi-Series Image Review with Spatial Registration*
    - *TV delineation, e.g., PET/CT*
    - *ITV evaluation, e.g, respiration, bladder filling*

Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Protocol Compliance QA (PCQA)*

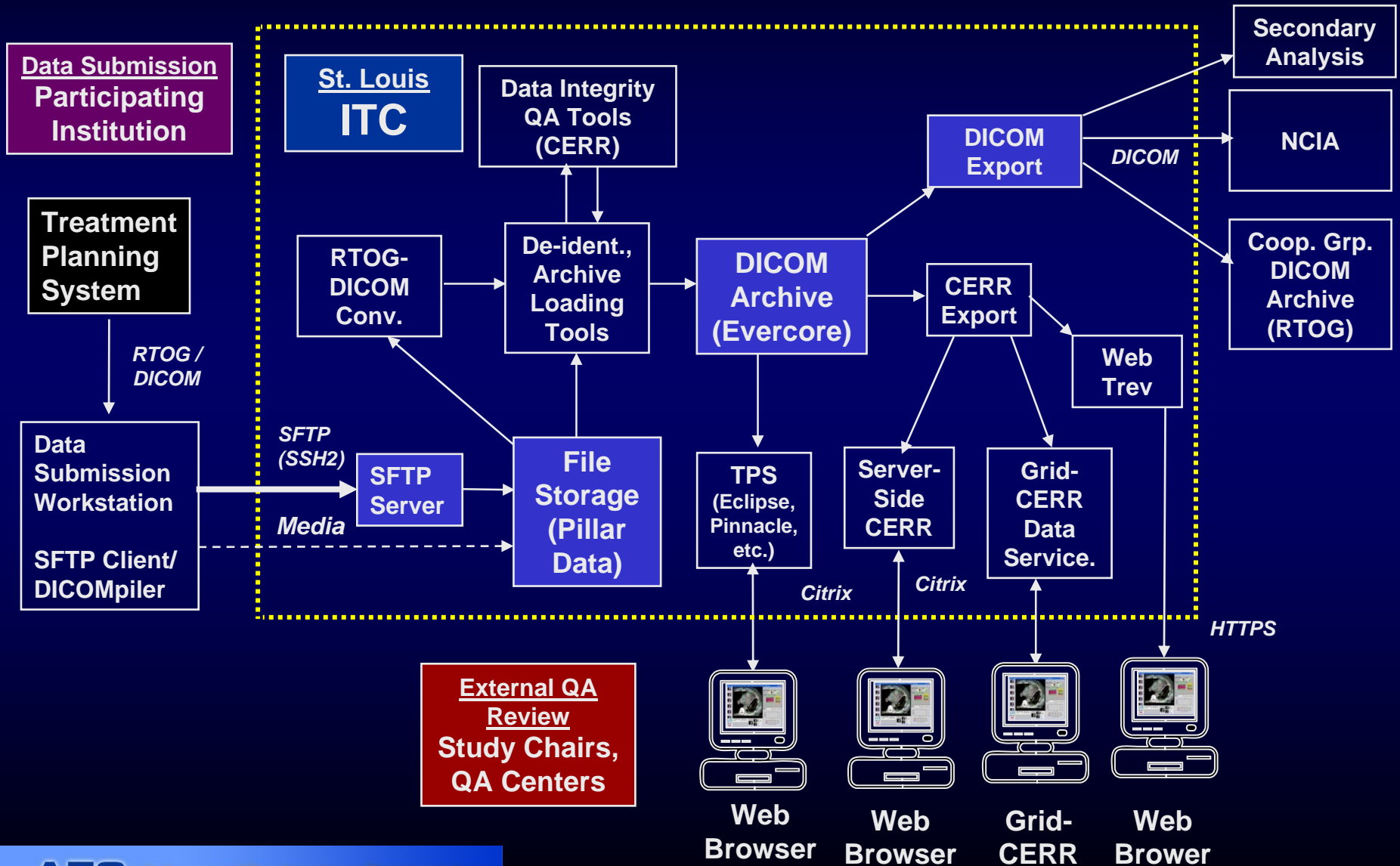- **ITC Review Tools Strategy**
  - *Remote Access to Server-Side review tools*
    - *CERR*
    - *Commercial TPS on ITC Server*
  - *Client-Side Review using caGrid / Virtual-PACS distribution of data*
    - *Grid-Enabled CERR*
    - *TPS Query/Retrieve from Virtual PACS*
- *Challenge*
  - *System and data security, i.e., controlling access to appropriate applications, data sets*
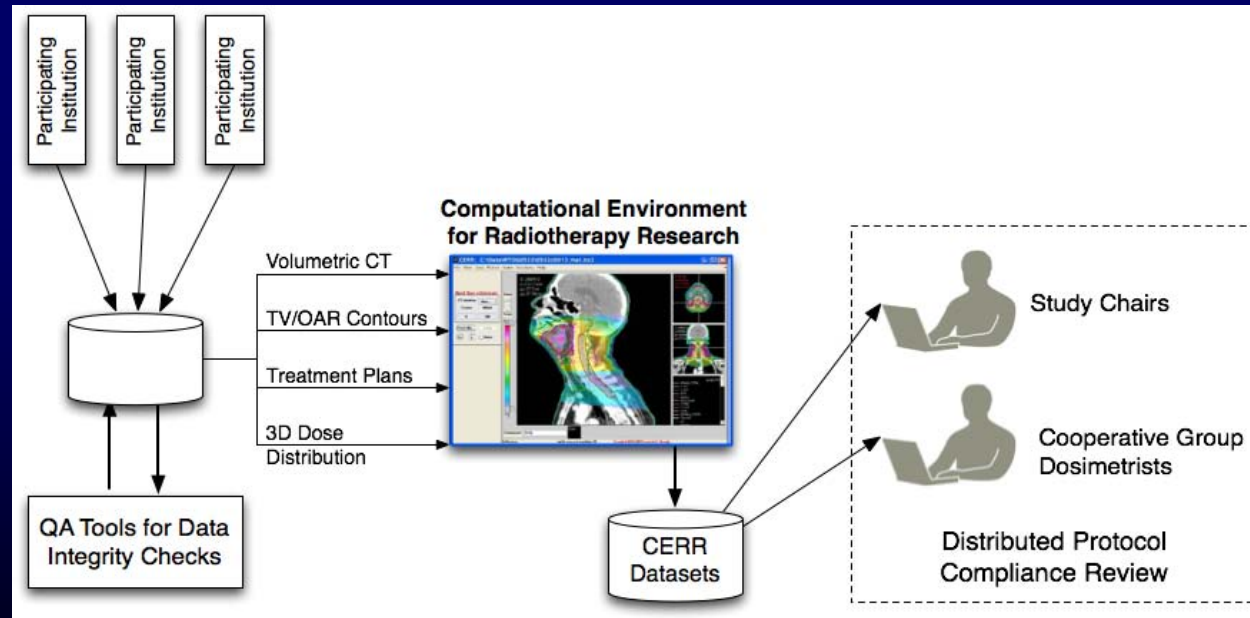
Treatment Planning & Verification

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Data Submission

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Data Integrity QA

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Protocol Compliance Review

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Outcomes Analysis

QuASA²R – *Development Plan*

Data Submission
Participating Institution

St. Louis
ITC

Data Integrity QA Tools (CERR)

Treatment Planning System

RTOG-DICOM Conv.

De-ident., Archive Loading Tools

DICOM Archive (Evercore)

DICOM Export

Secondary Analysis

NCIA

DICOM

Coop. Grp. DICOM Archive (RTOG)

CERR Export

Web Trev

RTOG / DICOM

Data Submission Workstation

SFTP Client/ DICOMpiler

SFTP (SSH2)

Media

SFTP Server

File Storage (Pillar Data)

TPS (Eclipse, Pinnacle, etc.)

Server-Side CERR

Grid-CERR Data Service.

Citrix

Citrix

HTTPS

External QA Review
Study Chairs, QA Centers

Web Browser 27

Web Browser

Grid-CERR

Web Brower

Grid Computing and RT Clinical Trials

Application of caGrid® Middleware to Facilitate Quality Assurance for Advanced Technology Radiation Therapy Clinical Trials

Joel H. Saltz[1], MD, PhD, Ashish Sharma[1], PhD, Tony C. Pan[1], MS,
Walter R. Bosch[2,3], DSc, Joseph O Deasy[3], PhD,
James A. Purdy[4], PhD

[1] Department of Biomedical Informatics, The Ohio State University, Columbus, OH
[2] Image-guided Therapy QA Center, Washington University, St. Louis, MO
[3] Department of Radiation Oncology, Washington University, St. Louis, MO
[4] Department of Radiation Oncology, UC Davis Cancer Center, Davis, CA

The caBIG In Vivo Imaging middleware is used to deploy existing CERR software as an integrated communication and review tool for Radiation Therapy clinical trials, institutional credentialing, and case quality assurance.

- Simplified and secure distribution of data to reviewers
- Capture reviewer scoring, modifications for subsequent analysis
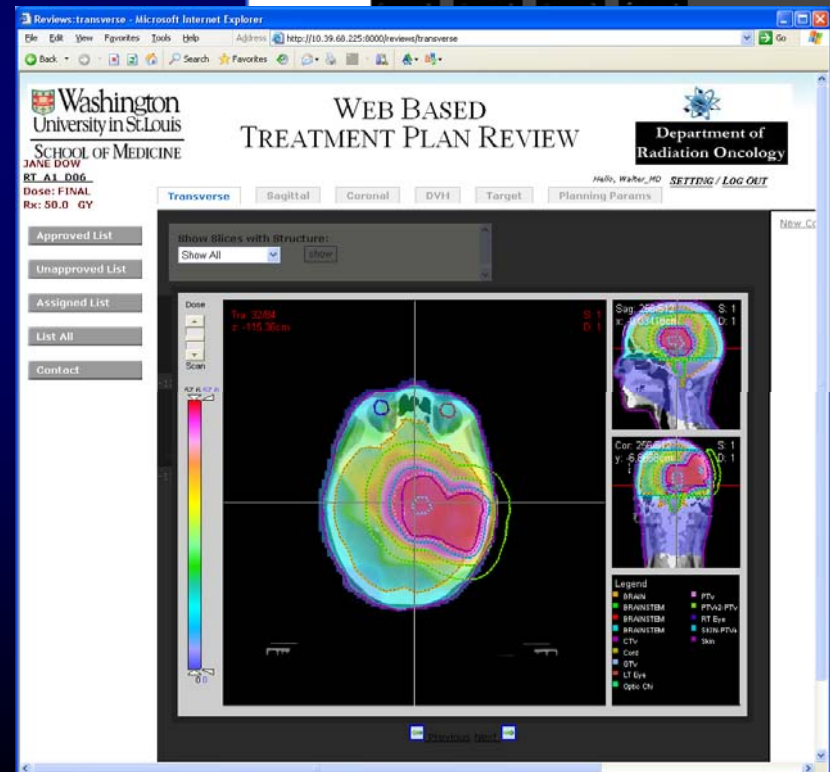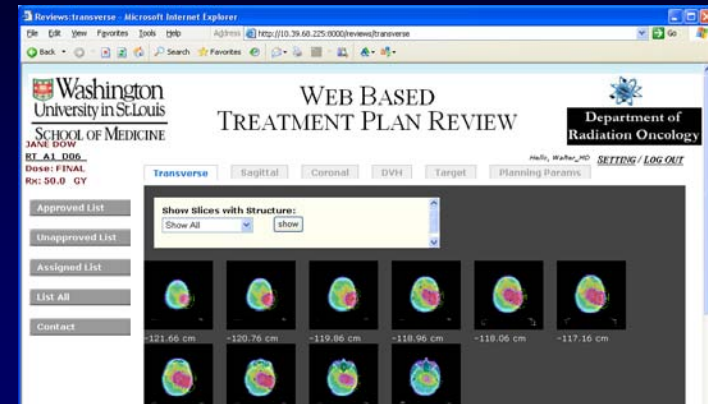
Components of Grid Enabled CERR

- A caGrid data service for storing CERR objects
  - Stores the metadata of the CERR MATLAB objects in a XML database
  - Provides Query and high performance data transfer from/to the client
- CERR client is modified to support grid interactions
  - Grid based Query/Retrieve interface
  - Grid security interface

Grid Q/R GUI
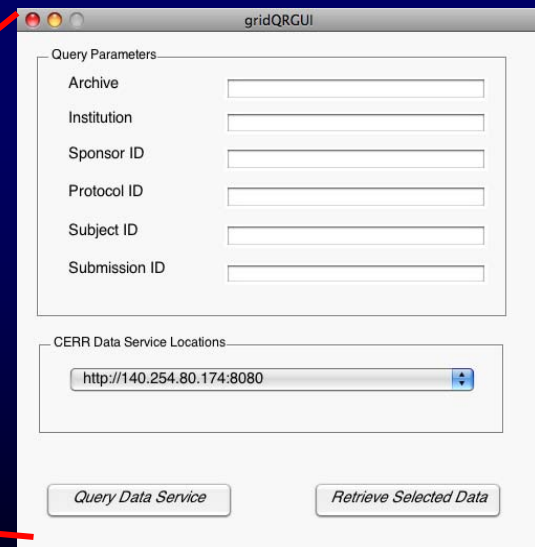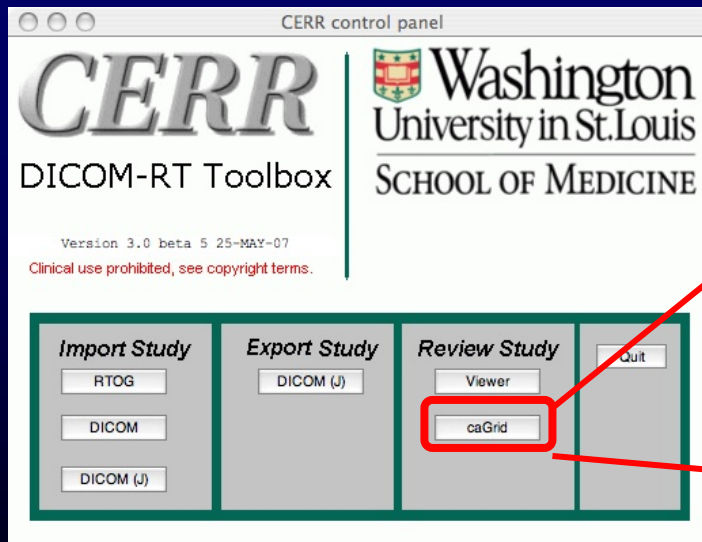
Web Based Treatment Plan Review (WebTrev)

- Worklist identifies cases to be reviewed
- Thumbnail-indexed sets of multi-planar (T/S/C) images
- QA reports of dose-volume statistics

Timeline for QuASA^{2}R Upgrades (1)

	Project	Date
1	Pillar Data Storage System • Stable support for existing QuASA^{2}R components • Flexible foundation for DICOM Archive	Installed Jan 2008, Upgraded May 2008 • Data backup, SFTP, RRT, Evercore operational
2	ITC DDIQA Server/Tape Backup Upgrade	Begin Summer 2008 • Phase 1 is operational • Phase 2 is in progress
3	DICOM-based RT Archive (TeraMedica) • Support for wide range of imaging and RT datasets	Installed June 2008 • Prelim. Configuration • Testing in progress
4	Data format conversion tools • DICOM conv. for legacy (RTOG) data • CERR conv. for phantom dosimetry • CERR conv. for distributed case review	Work in progress • Starting Jan 2007 • Batch conv. Apr 2008 • Data service is work in progress

Timeline for QuASA²R Upgrades (2)

	Project	Date
5	Digital Data Integrity QA workflow tools (CERR) • DDIQA Server • Data anonymization / ID reconciliation • Archive loading • Case data management (inventory, revision) • DICOM consistency checks (DVTk) • Structure naming / Structure editing / Dose summation	Begin Summer 2008 • DDIQA server, CERR installed May 2008 • Migration of existing tools to new platform in progress
6	Diagnostic Image/RT Review Tools • MIMvista • Velocity AI	Evaluation in progress • Q/R tests with Evercore June 2008
7	Grid-enabled CERR for production case review at ITC • Secure download, seamless review	Begin Spring 2008 • Collaborative work in progress with J. Deasy (WU), J. Saltz (Emory)

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Timeline for QuASA²R Upgrades (3)

	Project	Date
8	Server-side review tools • Remote Access to CERR for Multi-planar (T/S/C) contour and dose review • Multi-planar Static Image Review / QA Report Generator (WebTrev)	Begin Dec 2008 • Collaborative work in progress with J. Deasy (WU)
9	QuASA²R / Commercial TPS Integration • Eclipse • Pinnacle • CMS	Begin Summer 2009

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