Automated monitoring of treatment delivery

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Record and Verify Systems

Early generation of R&V Systems are;

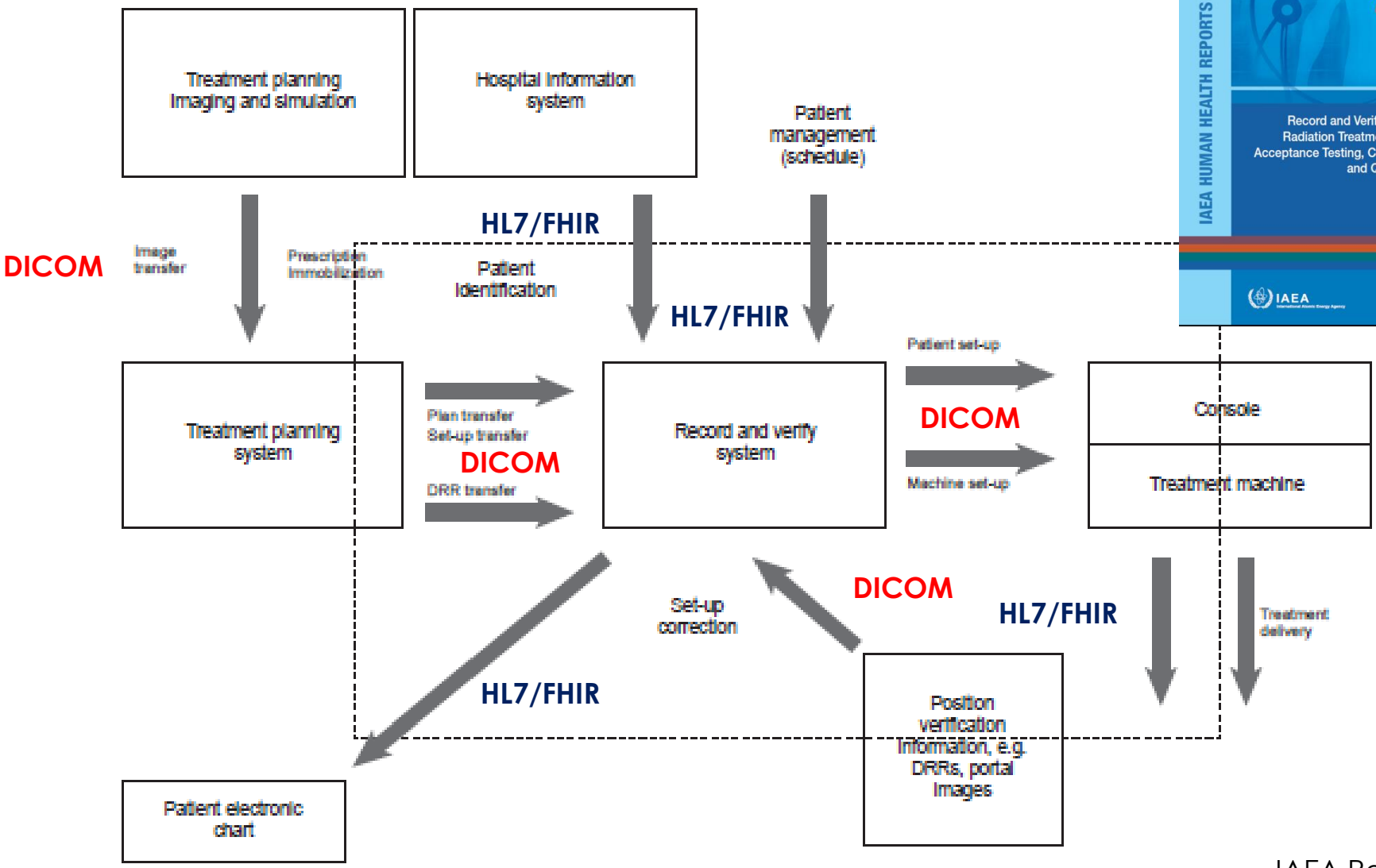
- computerized systems attached to individual treatment machines,
- designed to capture, before each beam delivery, several treatment parameters accessible through encoders and to compare them to the intended parameters,
- parameters entered manually or automatically transferred from the TPS or captured on the first treatment day to serve as a reference for the following fractions, and
- allowed partial or fully automated set-up

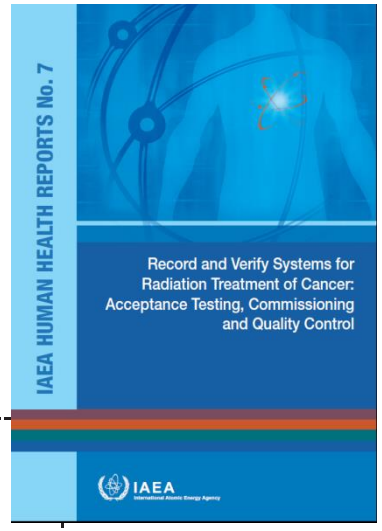
Record and Verify Systems

Present day R&V Systems are:

- Capable of all record, verify and assisted-setup functions,
- complete radiotherapy information management systems that interface with imaging systems, treatment planning computers and treatment delivery systems,
- capable of scheduling, data analysis, clinical assessment tools, image and photographic storage capabilities, dose alert functionality, intranet messaging services, and gateway and billing capabilities.

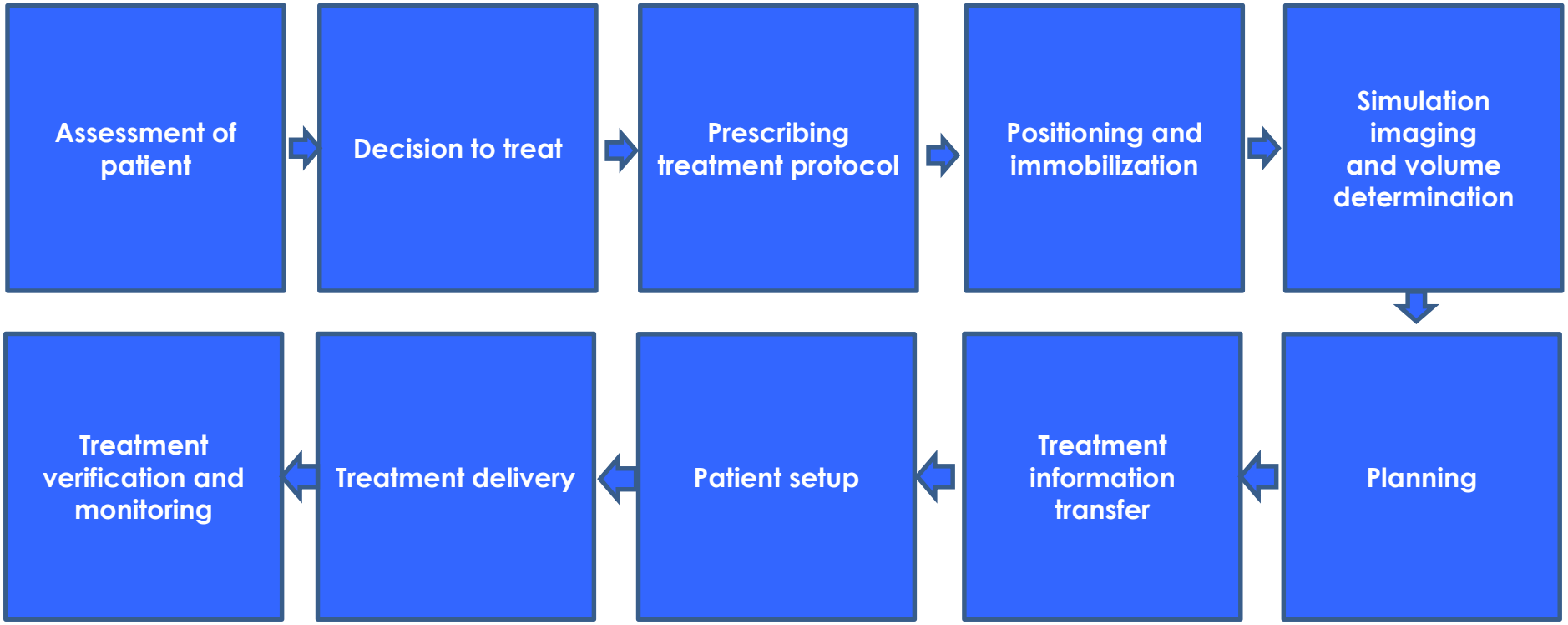
Data Exchange in Radiotherapy





IAEA Report # 7

Comprehensive Radiotherapy Workflow

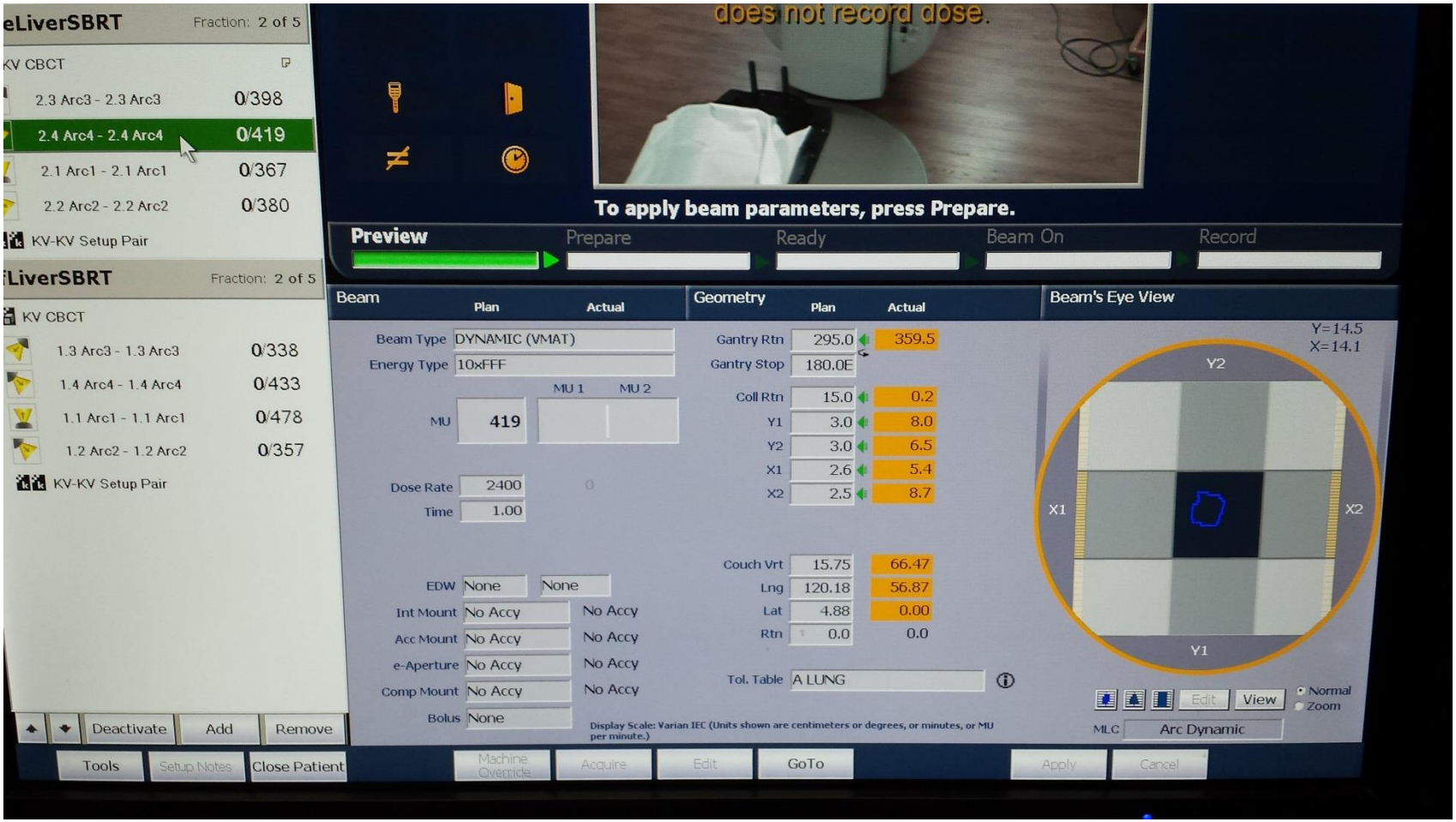


"**IT** plays a very important role in the continuum of radiotherapy; starting from decision support system to radiation treatment to response assessment to survivorship.

Hierarchical Organization of RVS Database

- Patient (unique ID): administrative data and identification photograph
- Treatment course: diagnostic and anatomical site
- Treatment plan (group of beams)
  - Prescription
    - dose point(s)/volumes
    - total dose, dose/fraction, breakpoints
  - Beam (field) (used either for set-up or treatment),
  - machine, modality, energy
  - MUs, time, MU rate (except for set-up)
  - mechanical set-up (collimator, gantry, table, etc.)
  - accessories (wedge, block, MLC, etc.)
  - tolerance table
  - reference image
  - field or set-up photographs
  - dose per field
  - free comments
- Treatment schedule

Record and Verify System GUI



RVS Functionalities

- Delivery System set-up (including patient positioner system)
  - If any of the set-up parameters does not match its intended value within the limits prescribed in the tolerance table, treatment delivery is prohibited, and a warning is given to the user.
- Monitor Units and Dose
  - 'consistency checks' in terms of data transfer from the source of primary dose calculation to the RVS.
- Verification of patient positioning (image comparison 2D/3D)
- Treatment data recording
  - number of MUs actually delivered from each beam at each fraction, with proper indication of the machine, course, plan and fraction identification, and exact time at which Tx delivered

Reducing Computer Errors

- Prevent errors from occurring
  - Robust system design. For example, one could simplify the choices presented to users so that they can't enter combinations of user input that lead to unanticipated software states,
- For systems that already exist;
  - Subsequent versions should be developed with engineers required to analyze the errors and warnings and see if there is a way to prevent the user from getting to the conditions that lead to these messages.

The New York Times

Sunday, January 24, 2010

The Radiation Boom
Radiation Offers New Cures, and Ways to Do Harm

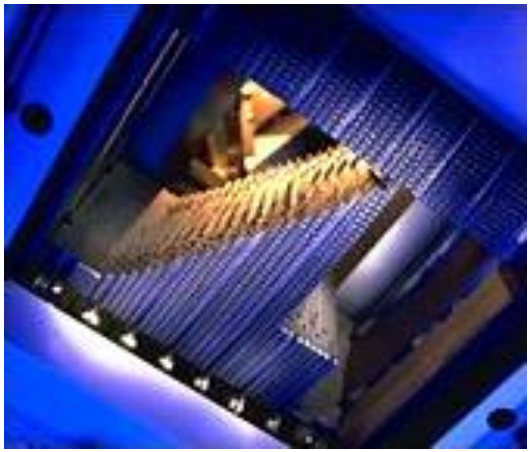
Scott Jerome-Parks

- MD requests tweak of plan to spare teeth
- Data transfer software crashes; allows corrupted data to be sent to machine
  - But gave a warning and allowed a choice
- Physicist makes the wrong choice
  - No QA checks were done
- Rush to treat
  - Therapists inattention
- Patient receives 13 Gy/fx; 3 fx; in 3 days
  - Patient was in agony after first Tx. Nurses and physicians ignored this symptom

What happened?

- March 14, 2005
  - Re-optimization work on “New Plan” starts on workstation 2 (WS2).
  - Treatment plan is changed. Existing fluence maps are deleted and re-optimized. New optimal fluence maps are saved to DB.
  - Final calculations are started, where MLC motion control points for IMRT are generated. Normal completion.

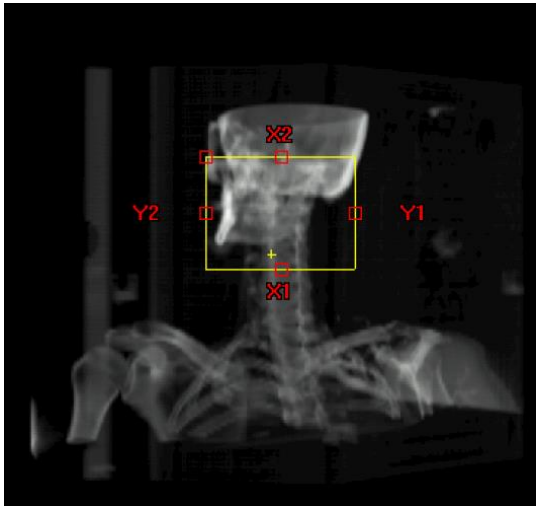
Multi Leaf Collimator (MLC)



What happened?

- March 14, 2005, 11 a.m.
  - "Save all" is started. All new and modified data should be saved to the DB.
  - In this process, data is sent to a **holding area** on the server, and **not saved permanently until ALL data elements have been received.**
  - In this case, data to be saved included: (1) actual fluence data, (2) a DRR and (3) the MLC control points

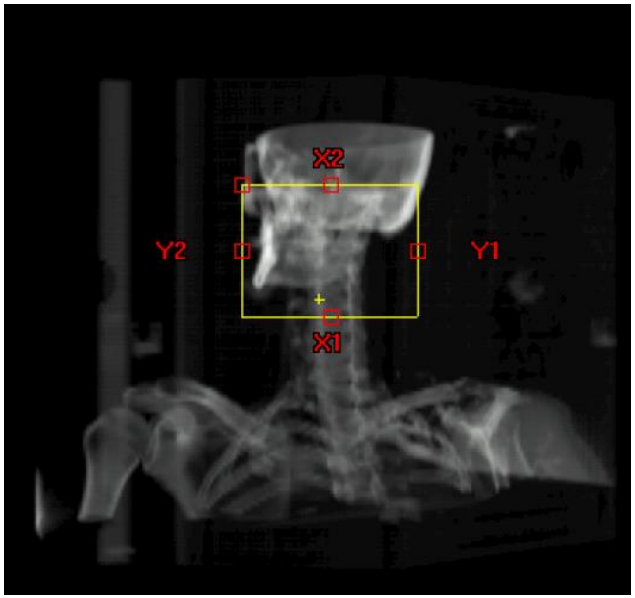
A Digitally Reconstructed Radiograph (DRR) of the patient



What happened?

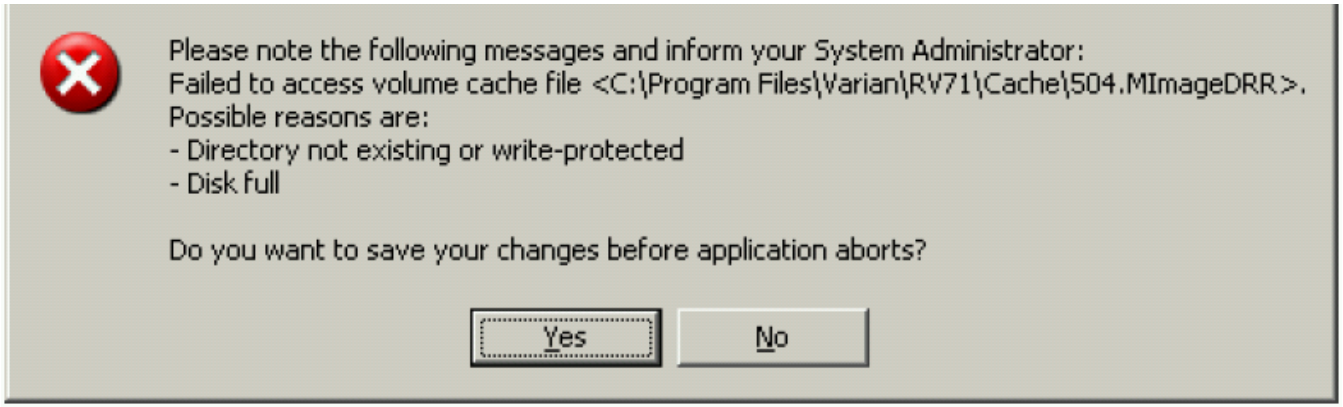
- March 14, 2005, 11 a.m.
- The actual fluence data is saved normally.
  - Next in line is the **DRR**. The "Save all" process continues with this, but is **not completed**.
  - Saving of **MLC control point data** would be after the DRR, but **will not start** because of the above.

A Digitally Reconstructed Radiograph (DRR) of the patient



What happened?

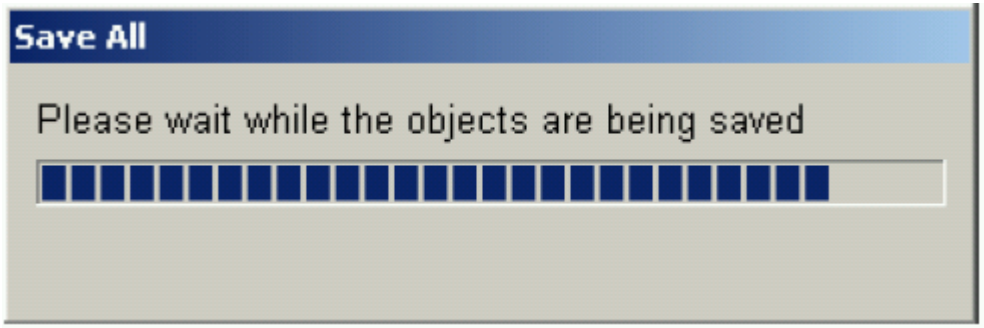
- March 14, 2005, 11 a.m.
  - An error message is displayed.
  - The user presses “Yes”, which begins a second, separate, save transaction.
  - MLC control point data is moved to the holding area.



The transaction error message displayed

What happened?

- March 14, 2005, 11.a.m.
  - The DRR is, however, still locked into the faulty first attempt to save.
  - This means the second save won't be able to complete.
  - The software would have **appeared to be frozen**.



The frozen state of the second "Save All" progress indication

What happened?

- March 14, 2005, 11.a.m.
  - The user then **terminated the TPS software manually**, probably with Ctrl-Alt-Del or Windows Task Manager
  - At manual termination, the DB performs a **"roll-back"** to return the data in the holding area to its last known valid state
  - The treatment plan now contains (1) actual fluence data; (2) not the full DRR; (3) no MLC control point data

Ctrl-Alt-Del

What happened?

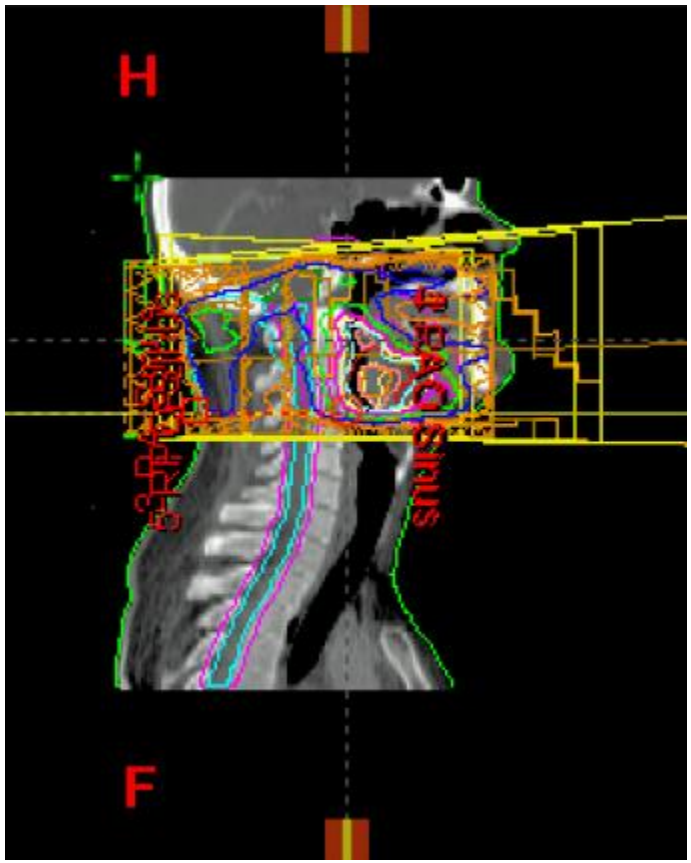
- March 14, 2005, 11.a.m.
  - Within 12 s, another workstation, WS1, is used to open the patients plan. The planner would have seen this:

Valid fluences were already saved. Calculations of dose distribution is now done by the planner and saved. MLC control point is not required for calculation of dose distribution.

Sagittal view of patient, with fields and dose distribution

What happened?

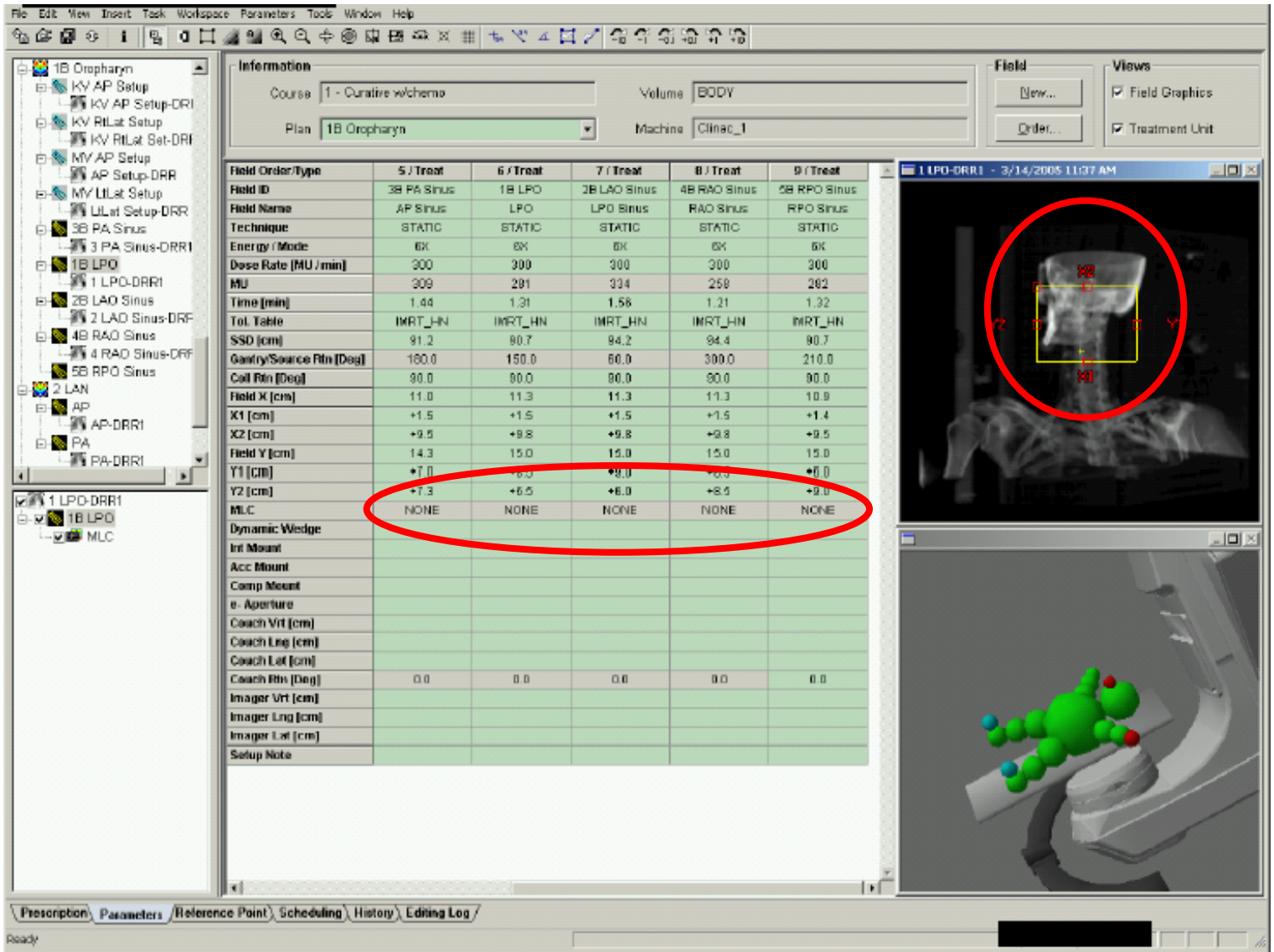
- March 14, 2005, 11.a.m.
  - No control point data is included in the plan.



The sagittal view should have looked like the one to the right, with MLCs

What happened?

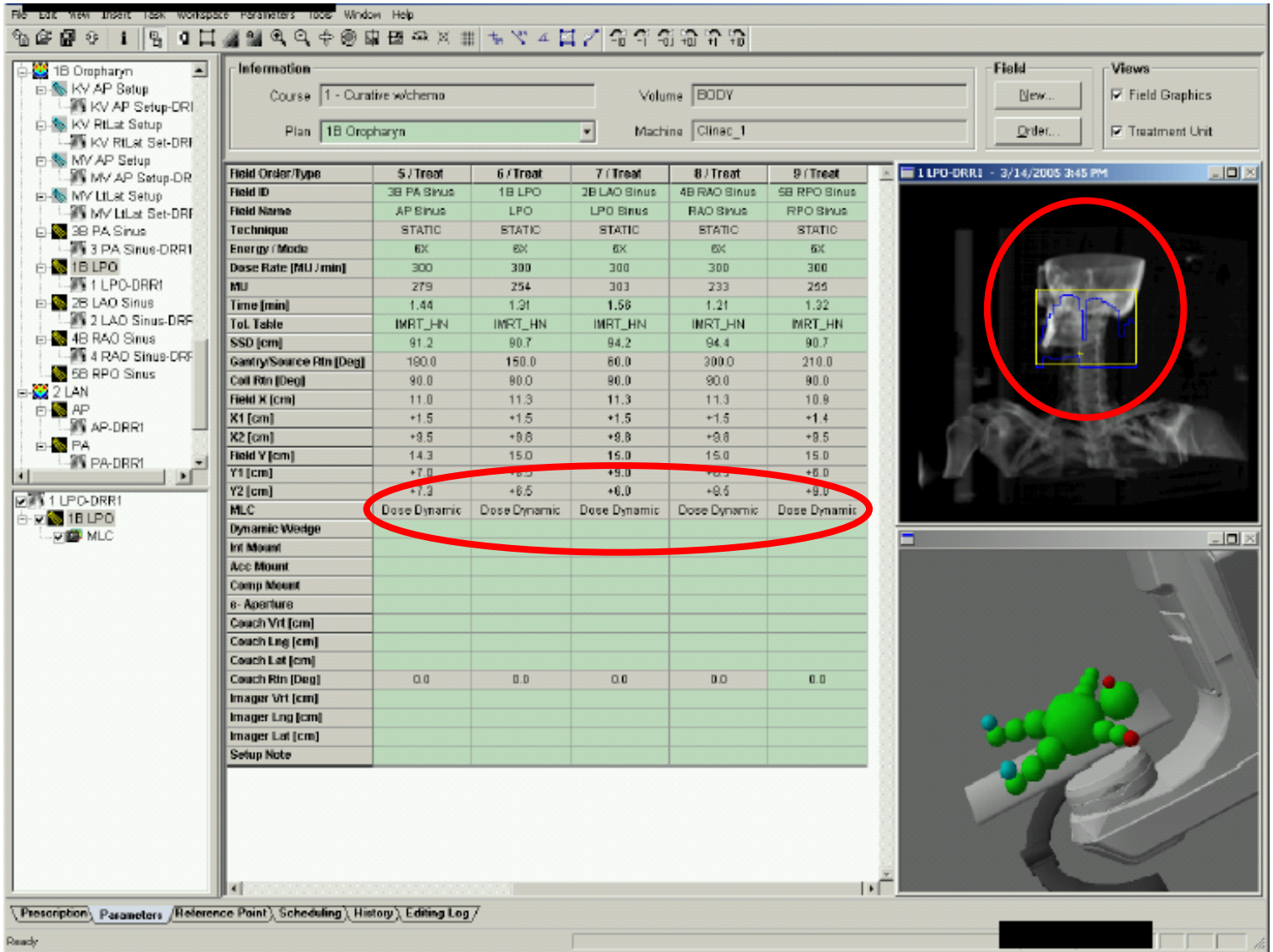
- Would have been seen on verification:



Field Order/Type	5 / Treat	6 / Treat	7 / Treat	8 / Treat	9 / Treat
Field ID	3B PA Sinus	1B LPO	2B LAO Sinus	4B RAO Sinus	5B RPO Sinus
Field Name	AP Sinus	LPO	LPO Sinus	RAO Sinus	RPO Sinus
Technique	STATIC	STATIC	STATIC	STATIC	STATIC
Energy / Mode	6X	6X	6X	6X	6X
Dose Rate [MU / min]	300	300	300	300	300
MU	309	281	334	259	282
Time [min]	1.44	1.31	1.56	1.21	1.32
Tot. Table	IMRT_HN	IMRT_HN	IMRT_HN	IMRT_HN	IMRT_HN
SSD [cm]	91.2	90.7	94.2	94.4	90.7
Gantry/Source Rtn [Deg]	180.0	150.0	60.0	300.0	210.0
Coll Rtn [Deg]	90.0	90.0	90.0	90.0	90.0
Field X [cm]	11.0	11.3	11.3	11.3	10.9
X1 [cm]	+1.5	+1.5	+1.5	+1.5	+1.4
X2 [cm]	+9.5	+9.8	+9.8	+9.8	+9.5
Field Y [cm]	14.3	15.0	15.0	15.0	15.0
Y1 [cm]	+7.0	+6.5	+6.0	+6.5	+6.0
Y2 [cm]	+7.3	+6.5	+6.0	+6.5	+6.0
MLC	NONE	NONE	NONE	NONE	NONE
Dynamic Wedge					
Int Mount					
Acc Mount					
Comp Mount					
e- Aperture					
Couch Vrt [cm]					
Couch Lng [cm]					
Couch Lat [cm]					
Couch Rtn [Deg]	0.0	0.0	0.0	0.0	0.0
Imager Vrt [cm]					
Imager Lng [cm]					
Imager Lat [cm]					
Setup Note					

What happened?

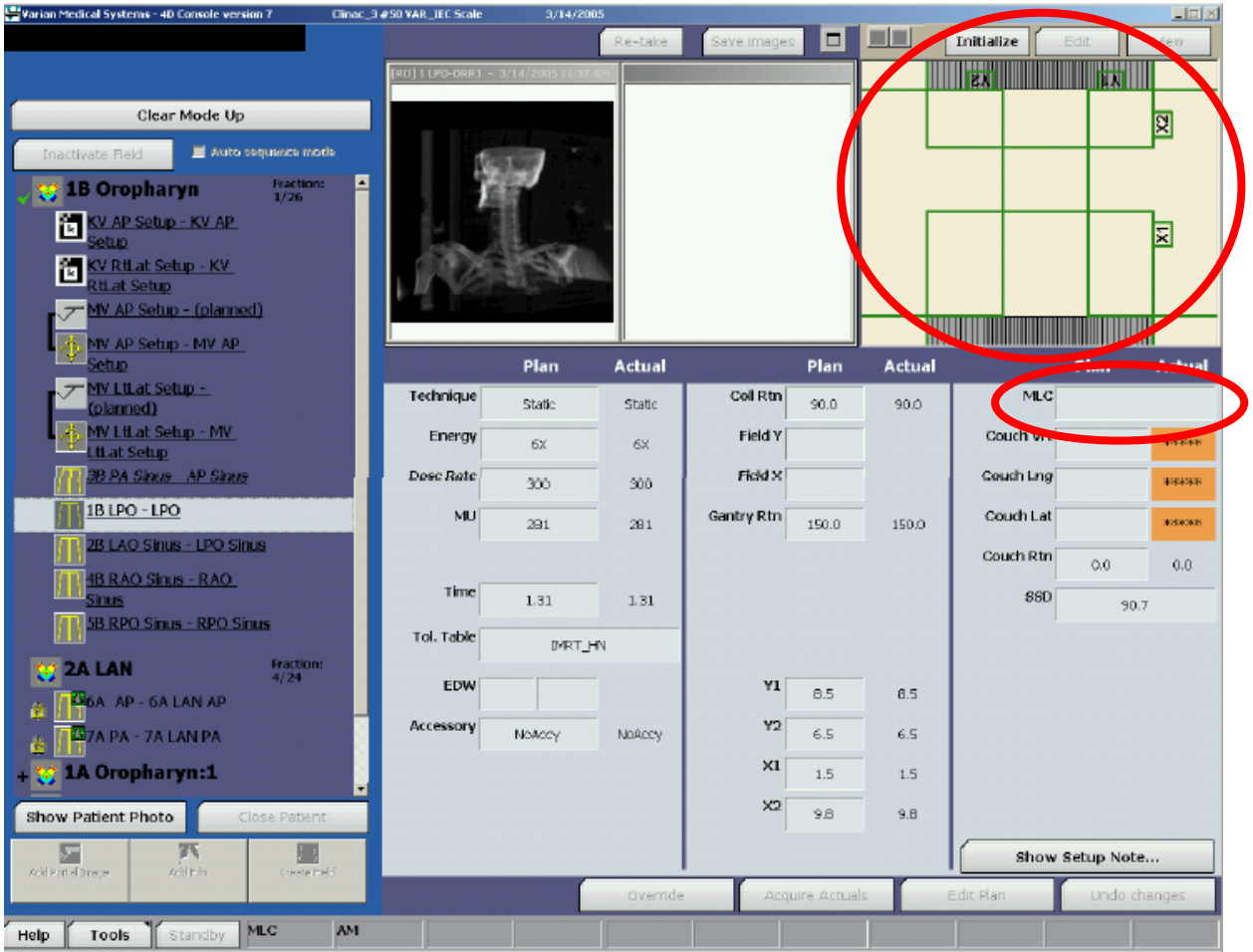
- <u>Should</u> have been seen on verification:



Field Order/Type	5 / Treat	6 / Treat	7 / Treat	8 / Treat	9 / Treat
Field ID	3B PA Sinus	1B LPO	2B LAO Sinus	4B RAO Sinus	5B RPO Sinus
Field Name	AP Sinus	LPO	LPO Sinus	RAO Sinus	RPO Sinus
Technique	STATIC	STATIC	STATIC	STATIC	STATIC
Energy / Mode	6X	6X	6X	6X	6X
Dose Rate [MU/min]	300	300	300	300	300
MU	279	254	303	233	255
Time [min]	1.44	1.31	1.56	1.21	1.32
Tol. Table	IMRT_HN	IMRT_HN	IMRT_HN	IMRT_HN	IMRT_HN
SSD [cm]	91.2	90.7	94.2	94.4	90.7
Gantry/Source Rtn [Deg]	180.0	150.0	60.0	300.0	210.0
Coll Rtn [Deg]	90.0	90.0	90.0	90.0	90.0
Field X [cm]	11.0	11.3	11.3	11.3	10.9
X1 [cm]	+1.5	+1.5	+1.5	+1.5	+1.4
X2 [cm]	+9.5	+9.8	+9.8	+9.8	+9.5
Field Y [cm]	14.3	15.0	15.0	15.0	15.0
Y1 [cm]	+7.0	[illegible]	+9.0	[illegible]	+8.0
Y2 [cm]	+7.3	+6.5	+6.0	+9.5	+9.0
MLC	Dose Dynamic	Dose Dynamic	Dose Dynamic	Dose Dynamic	Dose Dynamic
Dynamic Wedge					
Int Mount					
Acc Mount					
Comp Mount					
e- Aperture					
Couch Vrt [cm]					
Couch Lng [cm]					
Couch Lat [cm]					
Couch Rtn [Deg]	0.0	0.0	0.0	0.0	0.0
Imager Vrt [cm]					
Imager Lng [cm]					
Imager Lat [cm]					
Setup Note					

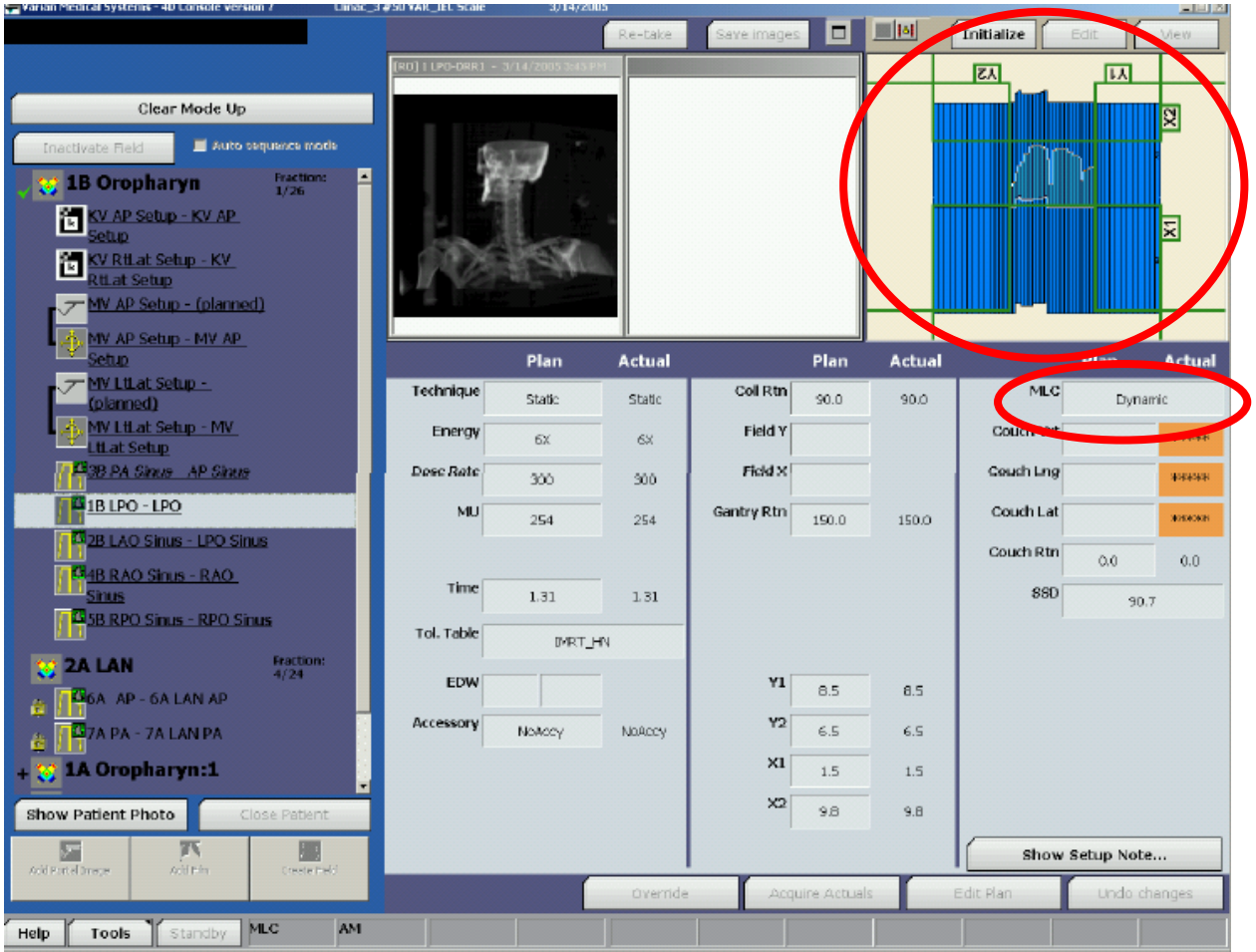
What happened?

- March 14, 2005, 1 p.m.
  - The patient is treated. The console screen would have indicated that MLC is not being used during treatment:



What happened?

- March 14, 2005, 1 p.m.
  - Expected display:



Lessons Learned

- Do what you should be doing according to a QA program
  - Never cut corners
- Comply with standard operating procedures
  - Do not rush
- Work with awareness
  - Do not assume anything
- Be alert when computer crashes
  - Always try to find out why a computer crash occurred

Human focus

Tech focus

Unambiguous and intuitive computer messages

Summary

1. Radiation Oncology is IT intense and it has substantial unmet need for IT integration and security in radiation oncology
2. Some progress has been made in ensuring interconnectivity and interoperability in radiation oncology but more work is needed.
3. There is an increasing need for reducing computer errors, fault management, and to prevent "message fatigue" in the design of software for radiotherapy applications.