Comparison of On-site and Off-site Evaluations of Dosimetry Data

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Abstract

Traditionally the Radiological Physics Center (RPC) quality assurance audits of institutions have been performed by a qualified RPC-Physicist on-site, and by a mailed TLD program that monitors machine output calibrations. In 1997, the RPC implemented a comprehensive off-site evaluation of institution dosimetry data and patient dose calculations. A preliminary analysis and comparison of the off-site evaluation for seventeen institutions with the results of their respective RPC on-site review will be presented.

The comparison shows that a detailed off-site evaluation of the calibration protocol parameters is not effective in identifying calibration dosimetry problems. In General, the off-site evaluation failed to identify percent-depth-dose and output factor discrepancies found at the institution during on-site reviews. However, PDD discrepancies found at two institutions by the off-site evaluation correctly predicted the on-site findings. The most frequently identified dosimetry problems come from the evaluation of wedge factors and off-axis factors. The off-site evaluation of patient dose calculations shows discrepancies that are significant, but not confirmed by the on-site visit. Our findings indicate that for the off-site dosimetry review to be more successful in predicting potential problems, the RPC needs to continue to refine its “standard” dosimetry data. The comparison of the results of the two reviews has allowed the RPC to evaluate the effectiveness of the remote review, to identify areas where it is more effective and how this remote evaluation program can be revised and improved.

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Introduction

The Radiological Physics Center (RPC) has provided radiotherapy quality assurance (QA) to institutions participating in NCI-Funded cooperative Clinical trials since 1972. The RPC is presently monitoring more than 1,200 megavoltage therapy facilities (i.e., approximately 3,000 machines, and 6,250 beams), which are actively participating in one or more cooperative groups. Traditionally the RPC audits are performed on-site by a qualified RPC-Physicist and by a TLD program to monitor machine output calibrations. The on-site dosimetry review is a labor-intensive component of the QA program; therefore, the large number of institutions monitored precludes frequent on-site visits. The RPC has a priority-score schema for on-site visits based on several monitored problem-indicators and the number of protocols patients treated by the institution. Since 1997, the RPC has been implementing a new off-site audit program to audit dosimetry data and dose calculation algorithms for all institutions it monitors. The main objectives of the off-site audit program are:

- To provide a baseline quality audit to all institutions participating in NCI cooperative trials
- To identify, evaluate, and resolve systematic errors in an institution's dosimetry data.
- To complement the RPC priority-score scheme based on unresolved discrepancies and by identifying Machine make and models for which RPC have limited on-site measurement data.

In this study, off-site audits have been reviewed for 78 institutions. 17 of these institutions have also received a on-site dosimetry review subsequent to submitting the off-site review materials. In this Report a comparison of the findings from the off-site and on-site reviews is presented.

Materials and Methods

Off-site Audits

Institutions are asked to complete information forms, submit copies of dosimetry data, and calculate machine set for several benchmark treatments. The Six Questionnaires send to the institutions requesting Information and Dosimetry Data include:

- **Institutions Demographics**
- **Photon and Electron Beam Data :** TG-21 Calculations, Output specification, Dosimetry data, QA procedures, Patient XRT information
- **Brachytherapy Data :** Source inventory and clinical values, source Certificates, basic dosimetry.
- **Instrumentation:** Calibration certificates, constancy checks, etc.
- **Treatment Planning Computer:** Demographics (XRT, and /or HDR), MU calculations, and
- **Benchmark Cases:** Wedge pair, and Lung field.

Materials and Methods

The following tools are used to evaluate institution's dosimetry:

Photon Beams:

- TLD history for output
- TG-21 Calculations
- Dosimetry data (Compare with RPC "standard" Data)
  - Relative output factors
  - Percentage Depth Dose
  - Off-Axis Factors
  - Wedge Factors

- **Electron Beams:**
  - TLD history for Output @ d_{max}
  - TG-21 Calculations
  - TLD @ depth (d_{80}/d_{50} Ratio-"RPC Standard")
- **Brachytherapy:**
  - Compares decay of manufacturer source certificate with institutions clinical source strength
- **Reference Cases**

Materials and Methods

Evaluation Criteria

The following criteria are used to evaluate the comparison of institution's dosimetry data against the RPC 'Standard Data"

- **Dosimetry parameters**
  - *±1 % for TG-21 Factors*
  - *±2 % of RPC standard for %DD, OAX and output Factors*
  - *±3 % of RPC standard for WTF*
  - *±3 mm for depth of a stated percentage depth-dose for electrons*
- **Brachytherapy**
  - *±2% agreement with Certificate source strength decay*
- **Reference cases**
  - *±5 % for dose delivery*

Resolution of Discrepancies

- Discrepancies exceeding ±3% or 3 mm are pursued
- Phone conversation, FAX, e-mail, etc., to physicist
- Repeat reference case
- On-site dosimetry review visit.

Materials and Methods

On-site Audit

Typical On-site dosimetry review Includes evaluation of:

- Selected machine dosimetry parameters
  - Photon Beams
  - Electron beams
  - Brachytherapy source calibrations
- QA procedures and documentation
- Treatment planning algorithms
- Patient dosimetry
- Personnel interview

Materials and Methods

Standard Data

An institution's dosimetry data can be compared against "standard" data for a given make and model accelerator.

The RPC database contains dosimetric characteristics obtained during on-site review visits for more than 1300 linear accelerator photon beams. Analysis of these data suggests that machines of the same make and model have nearly identical dosimetry properties. The RPC has identified "Standard" dosimetry data for 45 different make, model, and energy of linear accelerator beams. The methodology for the measurements and comparison between the RPC standard data and the institution's data has been previously presented.[10, 11]

The RPC has developed tables of standard data for field size dependence (FSD), wedge factors, and off-axis factors, percent-depth-dose data, for different energies and megavoltage machine makes and models.

Materials and Methods

RPC "Standard Data"

Standard Data for Photon Beams Include:

- Output factors
- In-air OA profile
- Depth dose data (Ref. 6 to17)
- WTF and TF (Ref. 18)
- WTF field size and depth dose (Ref.19)
- Asymmetric jaw (khan technique)(Ref. 20)

Standard Data for Electron Beams Include:

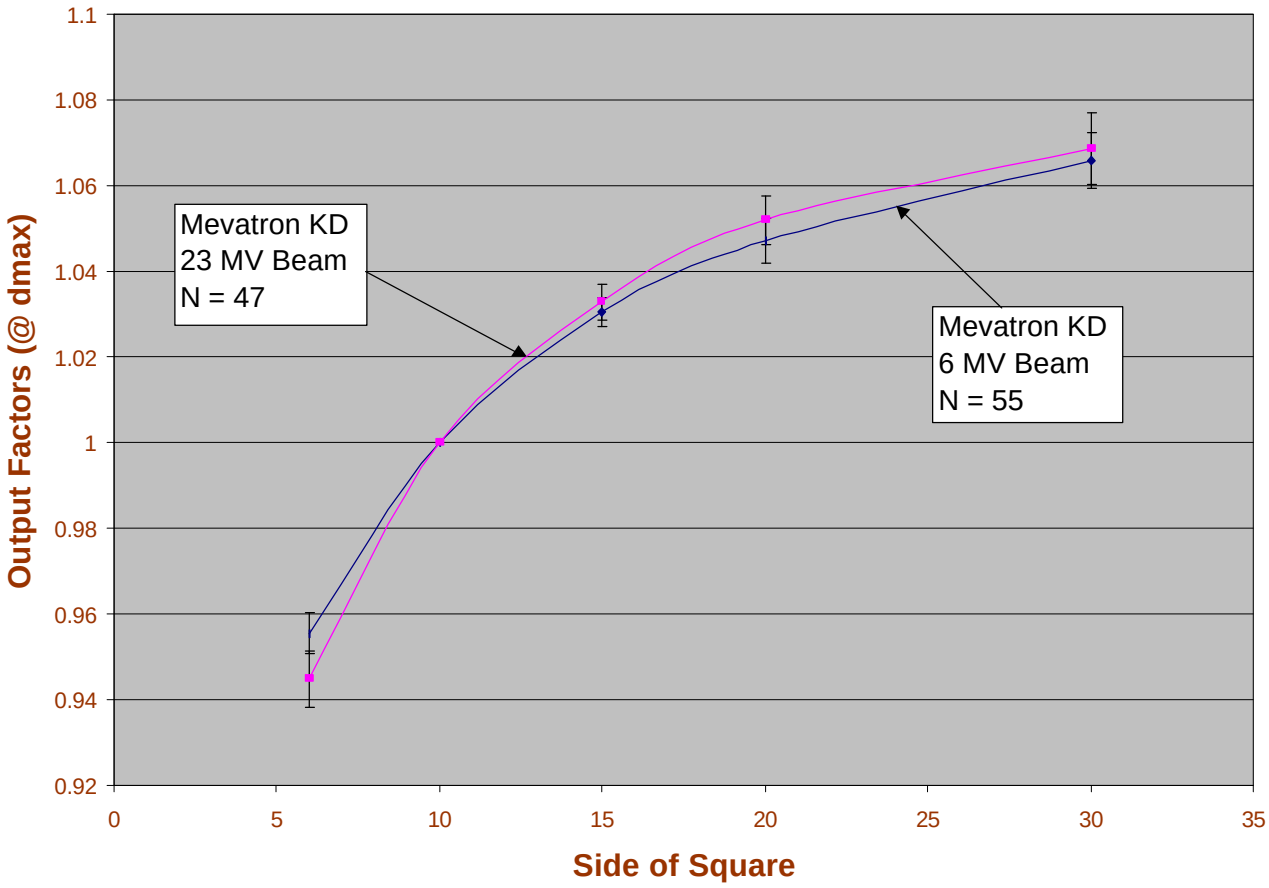
- Depth dose data
- Extended dist. Factor

■ Brachytherapy

- LDR & HDR dose per integrated activity for pt. A & B

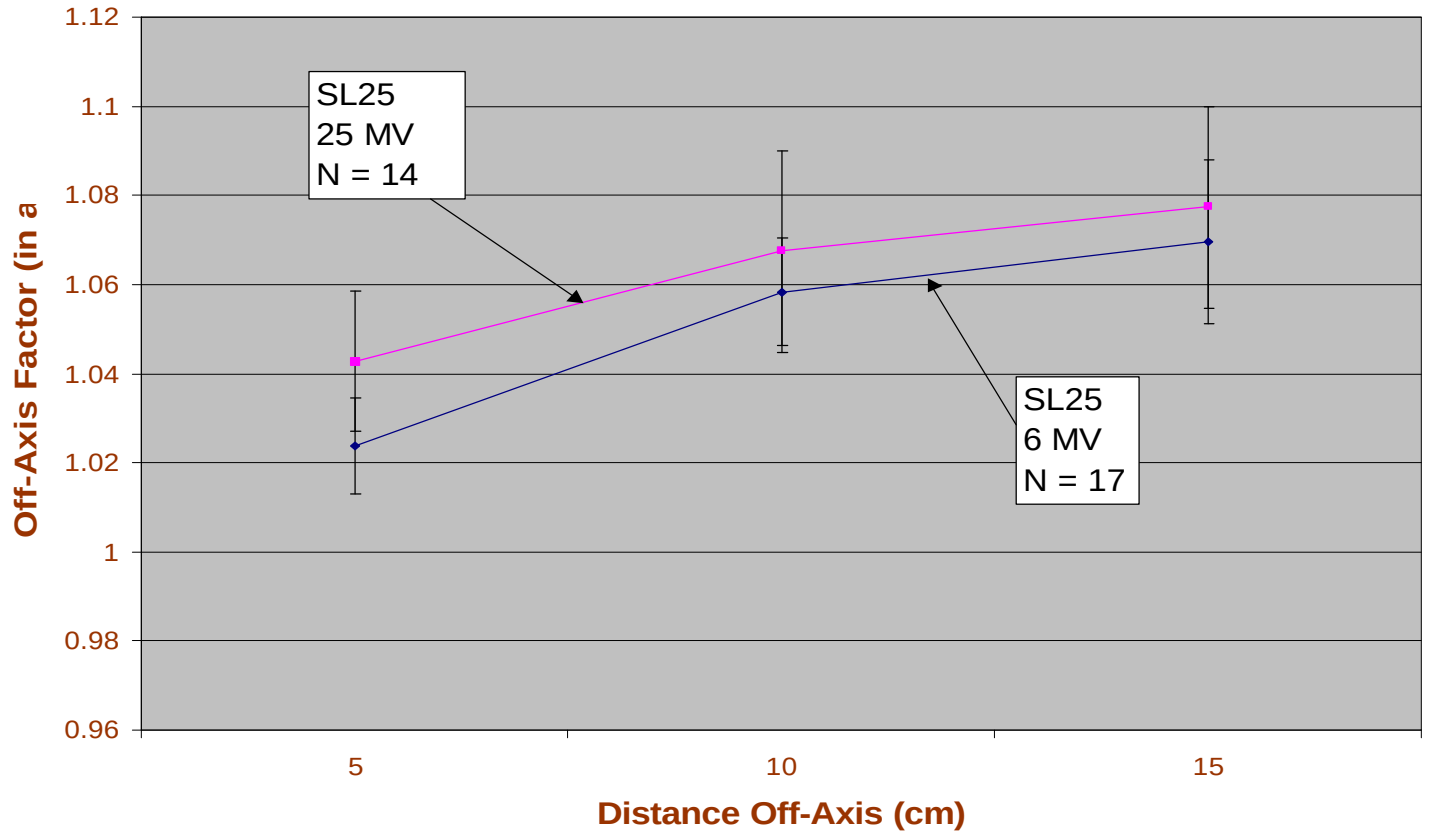
Materials and Methods

The following Sample of RPC Standard Data for Output Factors for a Mevatron KD (6 and 23 MV X-ray Beams) shows the accuracy of the standard.



Materials and Methods

This graph shows the RPC "Standard Data" for Off-axis Factors for a Philips SL-25 (6 and 25 MV Beam)



Materials and Methods

RPC Standard Data-Percent Depth Dose Data
Clinac 2100C 18 MV

Field Size (cm x cm)	Depth (cm)	N	Mean	Standard Deviation	Standard Data (ref. 12)
6 x 6	7	59	0.907	0.007	0.898
	10	72	0.799	0.006	0.796
	15	72	0.646	0.005	0.640
	20	72	0.522	0.004	0.515
10 x 10	7	59	0.900	0.007	0.890
	10	72	0.798	0.006	0.789
	15	72	0.651	0.005	0.640
	20	72	0.531	0.004	0.523
20 x 20	7	59	0.887	0.009	0.870
	10	72	0.793	0.008	0.776
	15	72	0.656	0.007	0.641
	20	72	0.542	0.006	0.528

Materials and Methods

This Table shows RPC "Standard Data" for Percentage Depth Dose Data for 14 models of LINACS.

Machine	Energy(MV)	Data Sets	"Best Fit"*	Min(%)	Max(%)
Clinac 4/100	4	19	Biggs[10]	-1.1	0.5
SHM 4	4	17	BJR #11 4 MV)[11]	-1.5	1.5
Clinac 2100	6	17	Barnes[7]	-0.5	0.6
Clinac 6/100	6	79	Coffey[13]	-0.6	1.2
Clinac 6	6	34	Fontenla[12]	-0.7	0.6
Mevatron 6	6	22	BJR #11 (6 MV)[11]	-1.3	0.2
Mevatron KD	6	15	Al-Ghazi[17]	-0.9	0.4
SL75	8	16	BJR #17 (8 MV)[11]	0	1.9
Clinac 1	10	69	Purdy[8]	-0.4	-0.1
Mevatron 74	10	16	Keller[14]	-0.8	0.6
Mevatron 77	15	7	BJR #17 (16 MV)[11]	-0.4	1.5
Clinac 1800	18	16	BJR #17 (21 MV)[11]	-0.4	0.7
Mevatron KD	18-23	10	Al-Gazi[17]	0.1	0.5
Sagittaire	25	7	BJR #17 (25 MV)[11]	-0.3	0.8

Materials and Methods

Analysis of Data

The RPC has received dosimetry data for 218 photon beams from 78 institutions. After a preliminary analysis of these 218 photon beams, several institutions were prioritized for an on-site dosimetry review based on the results of the comparison of institution's dosimetry data to the RPC "standard" data. Other institutions were prioritized for on-site review for other reasons.

To date seventeen institutions 67 photon beams have received both on-site and off-site dosimetry review.

The following is the comparison of the parameters measured on-site with the values submitted by the institution.

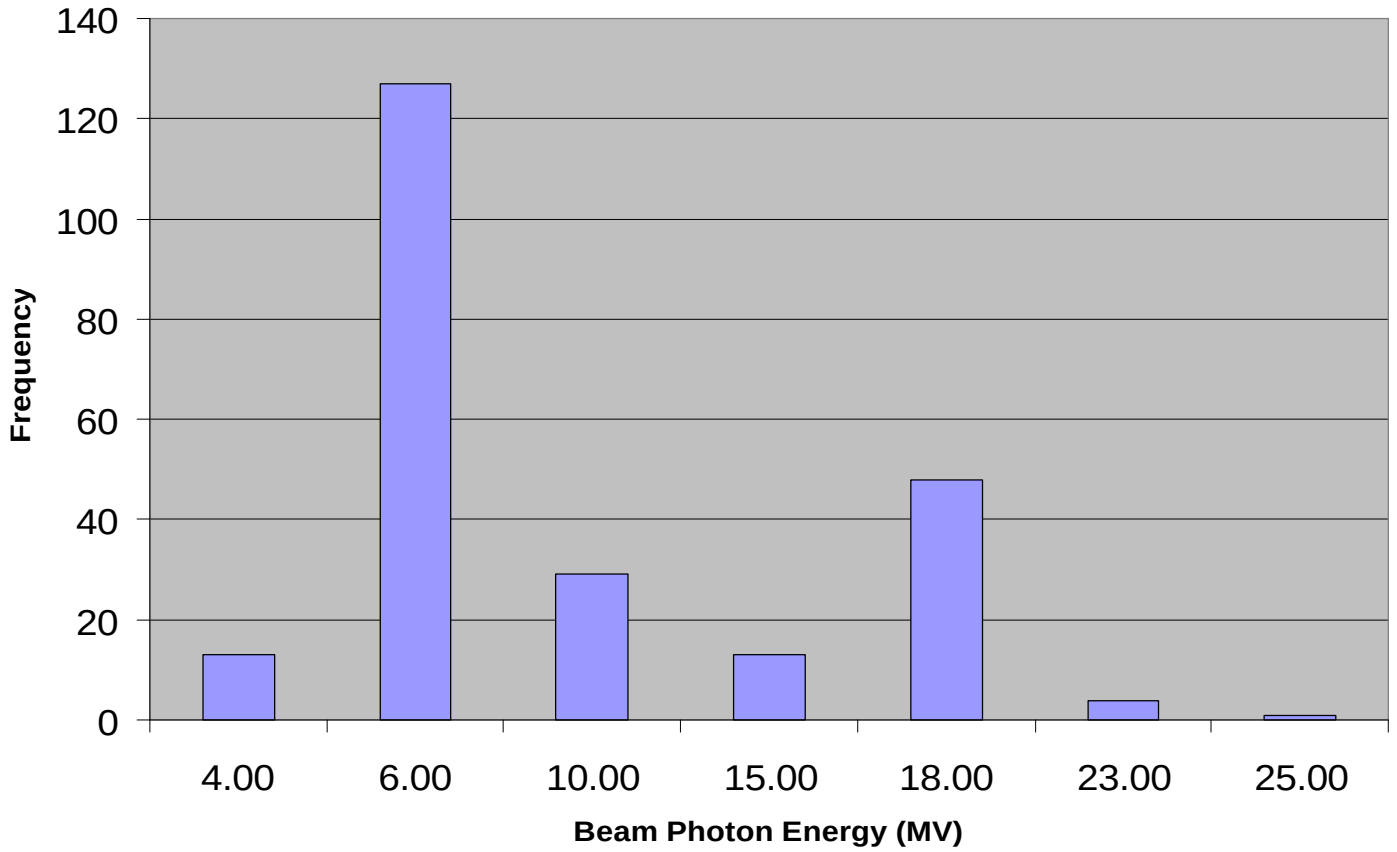
Results-Dosimetry Data

Table I. Summarizes the sensitivity and specificity of the off-site review to identify dosimetry discrepancies for the parameters investigated.

Tables II - IV list the actual data, Institution data, Standard Data, and RPC on site- Measurements for various parameters investigated.

Demographics

Data collected from 78 institutions show the following distribution of Photon Beams energies regardless of machine model and make.



Demographics

Data collected from 78 institutions show the following distribution of Photon Beams by manufacturer and single or multi modality LINACS.

Machine	Modality	# of Machines	# of Models	# of Beams
Cobalt-60	Single	3	3	5
Varian	Single	9	8	47
	Multi	14	3	121
Seamens	Single	4	4	6
	Multi	8	2	46
Philips	Multi	2	2	3
Mitsubishi	Single	1	1	2
GE	Multi	3	3	4
Dynaray	Single	1	1	1

Results

Table I. the number of photon beams in each category for each dosimetry parameter compared.

Total Number of Photon Beams Analyzed	**TG-21 Factors**	**OPF**	**PDD**	**OAF**	**WF**
	42	45	49	23	40
Number of Photon Beams, Off-site review found a parameter out of criteria	4	5	5	8	12
Number of Photon Beams Off-site review found a parameter out of criteria and Confirmed by on-site review	0	0	1	2	2
No. of Photon Beams Off-site review found a parameter out of criteria but not Confirmed by on-site review	4	5	4	6	10
Number of Photon Beams with a parameter within criteria that were found out of criteria by on-site review	0	0	0	1	9
Total number of photon beams with a parameter found out of criteria by either review	0	0	1	3	11

Results

Table II. Comparison of WF for those photon beams with significant discrepancies.

Machine	Did Off-site Review found a problem?	Did On-site Review found a problem?	Institution's Value	RPC Standard Value	Measured Value on-site	Inst./Std	Meas./Inst.
Clinac 2100C (6MV)	Yes	Yes	0.515	0.546	0.520	0.943	0.950
Clinac 2100C(6MV)	Yes	Yes	0.403	0.415	0.417	0.971	1.035
Clinac 2100C(6MV)	No	Yes	0.492	0.491	0.505	1.002	1.026
Clinac 2100C(6MV)	No	Yes	0.502	0.491	0.525	1.022	1.046
Clinac 2100C(10MV)	No	Yes	0.483	0.491	0.505	0.984	1.037
Clinac 2100C(15MV)	No	Yes	0.536	0.530	0.555	1.011	1.035
Clinac 600C(6MV)	No	Yes	0.500	0.499	0.516	1.002	1.032
Clinac 6/100C(6MV)	No	Yes	0.473	0.480	0.493	1.015	1.042
Clinac 1800(6MV)	No	Yes	0.484	0.485	0.500	1.002	1.030
Mevatron KD2(6MV)	No	Yes	0.320	0.314	0.329	1.019	1.028
Clinac 600C(6MV)	No	Yes	0.495	0.499	0.495	1.008	1.030
Clinac 2100C(6MV)	Yes	No	0.402	0.415	0.403	1.032	1.000
Clinac 2100C(18MV)	Yes	No	0.403	0.439	0.410	1.089	1.017
Clinac 1800(18MV)	Yes	No	0.509	0.522	0.506	0.975	0.994
Mev_ KD2 (15MV)	Yes	No	0.402	0.392	0.395	1.026	0.983
Clinac 2100C(18MV)	Yes	No	0.667	0.643	0.661	1.037	0.990
Clinac 6/100(6MV)	Yes	No	0.396	0.415	0.401	0.954	1.013
Mev_ KD2(6MV)	Yes	No	0.420	0.447	0.425	0.940	1.012
Clinac 2100C(18MV)	Yes	No	0.351	0.392	0.350	1.026	0.997
Clinac 2100C(6MV)	Yes	No	0.424	0.439	0.426	0.966	1.005
Clinac 2100C(6MV)	Yes	No	0.403	0.415	0.402	1.03	1.000

Results

Table III. Comparison of off-site and on-site review of Percent-Depth-Dose.

Machine	Did Off-site review found a problem?	Did on-site review found a problem?	Institution's Value	RPC Standard	Measured Value on-site	Inst./STD	Meas./Inst.
Cl 2100 (6MV)	Yes	No	0.439	0.427	0.433	1.028	0.986
Cl2100(6MV)	Yes	No	0.400	0.388	0.394	1.031	0.985
Cl600(6MV)	Yes	Yes	0.344	0.354	0.354	0.972	1.029
Cl1800(6MV)	Yes	No	0.400	0.388	0.394	1.031	0.985
Cl1800(6MV)	Yes	No	0.439	0.425	0.434	1.033	0.990

Results

Table IV. Comparison of off-site and on-site review of reference cases

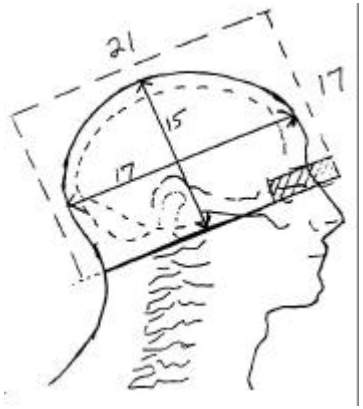
Machine	Reference Brain Case		Reference Lung Case Point A		Reference Lung Case Point B		Reference Lung Case Point C	
	Off-site	On-site	Off-site	On-site	Off-site	On-site	Off-site	On-site
Cl 600(6MV)	0.99	1.01	1.01	1.02	1.01	1.08	1.00	1.05
Cl 2100C(6MV)	0.99	1.00	0.99	0.99	0.98	1.01	0.98	1.01
Cl 1800(6MV)	0.96	1.00	0.98	1.00	0.99	--	0.97	--
Cl6/100(6MV)	1.00	1.00	1.00	1.00	1.03	0.99	1.04	0.99
Cl2100(6MV)	0.96	1.00	0.98	1.00	1.00	0.96	1.04	0.99
Mev_ KD2(6MV)	0.99	0.98	1.03	1.00	1.03	1.00	1.00	1.00
Cl2100C(6MV)	1.03	1.01	1.01	1.01	1.03	1.02	1.02	1.00
Cl2100C(6MV)	1.01	1.01	1.02	1.00	1.04	1.02	1.01	0.99
Cl2100C(6MV)	1.00	1.00	1.00	0.99	1.03	0.98	1.04	1.00
Cl6/100(6MV)	1.02	1.01	1.01	1.01	1.00	1.01	1.04	1.00
Cl1800(6MV)	0.98	1.00	0.98	0.99	0.98	1.01	0.98	1.02
Cl2100C(23MV)	1.01	1.00	1.01	1.00	1.02	1.00	1.01	1.02

Benchmark Cases

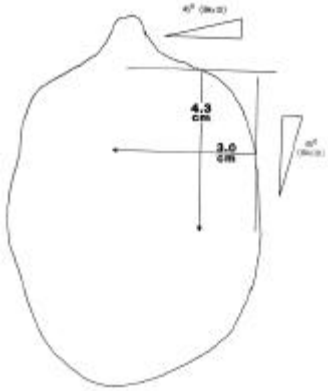
Cases used to test the Institution's Treatment Planning Computers

- **Calculations use Institutions data and RPC Algorithms**
- **Cases 1 to 4 used for On-Site Reviews**
- **Cases 2 and 3 used for Off-Site Reviews**

(1) Whole Brain (test eff. Area)

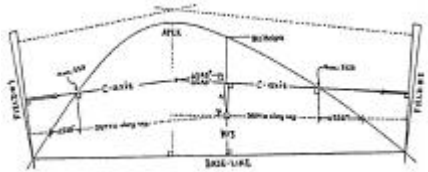


(2) Wedge pair (test WF)



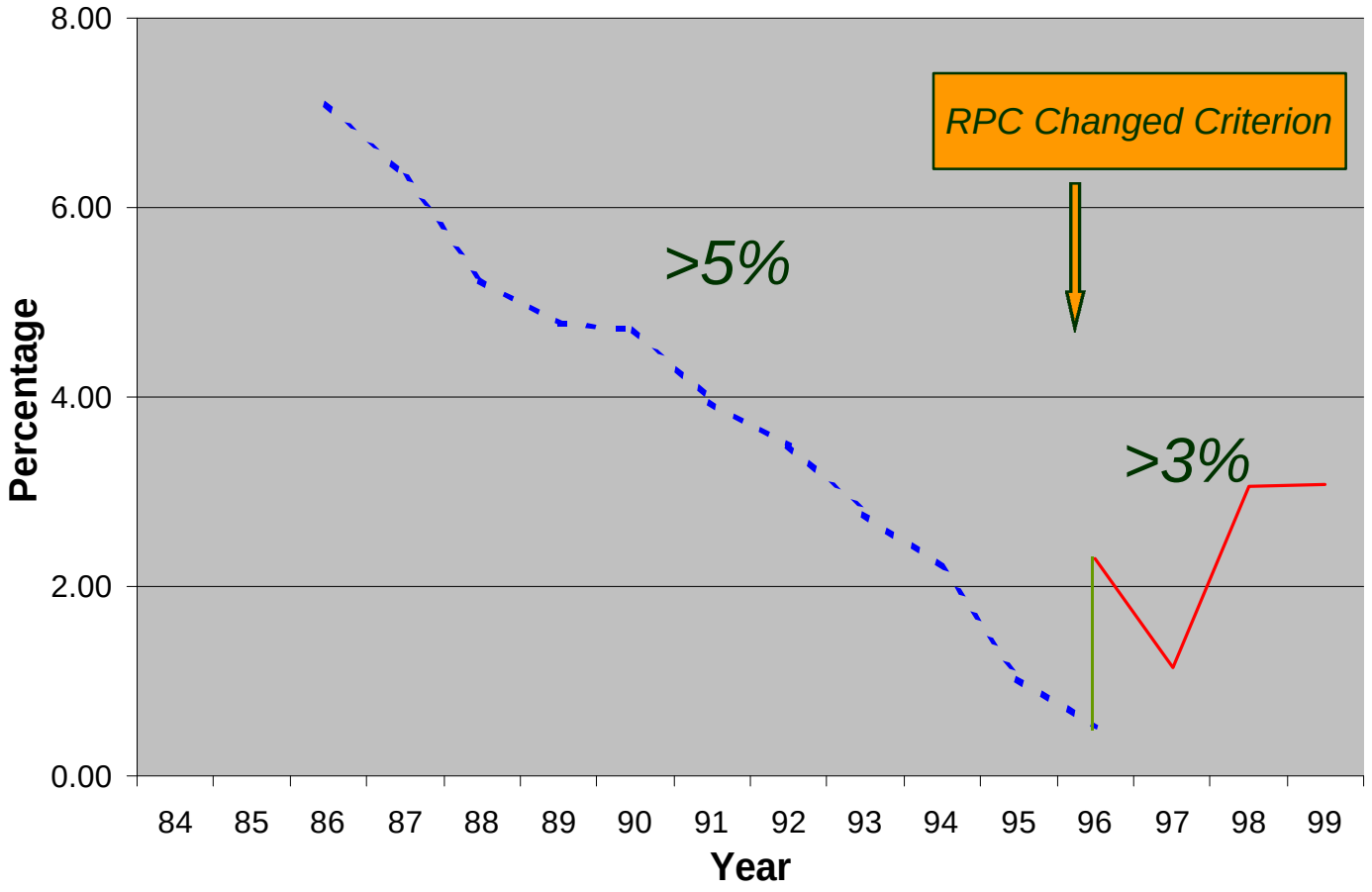
(3) Lung (IRREG.)

(4) Breast (Breast Problems.)



Benchmark Cases

This graph shows the percentage of Benchmark Cases reviewed during on-site visits that are out of criteria since 1986.



Benchmark Cases

This Table summarizes the analysis of 75 institution's Off-site Dosimetry Review. The RPC used the institution's dosimetry data and RPC calculation techniques in the review.
The number of cases out of criteria are consistent with the numbers of cases found out of criteria for on-site review visits.

Case	Acceptance Criterion	% outside the Criterion
Wedge Pair on CAX	± 3%	10.6%
Lung on CAX	± 3%	0.0%
Lung Lower Medstim.	± 3%	7.2%
Lung Supraclav.	± 3%	9.6%

Conclusions

The In its present format, the off-site review process has not been successful.

- Best case 20% of discrepancies suggested by off-site review were verified by on-site visit.
- Off-site evaluation failed to identify wedge transmission problems in a significant number of cases.
- Wedge transmission continue to be a major concern identified by both the off-site and on-site reviews.

- Data are being re evaluated to identify causes for failure of this monitoring tool.

Two Causes have already been identified. These are:

- An Institution which has multiple sets of data- one set was submitted for off-site review, and another for on-site review.
- Incomplete data were submitted for the off-site review. This is most significant for wedge transmission and off-axis data.

References

1. J.H. Cundiff et al.: Am. J. Task Group 21, Radiation Therapy Committee, American Association of Physicists in Medicine. "A Protocol for the Determination of Absorbed Dose from High-Energy Photon and Electron Beams", *Medical. Physics.* 10:741-771 (1983).
2. American Association of Physicists in Medicine Report #21: "*Specification of Brachytherapy Source Strength*", 1987.
3. R. Gastorf, L. Humphries, M. Rozenfeld. Cylindrical Chamber dimensions and the corresponding, A_{wall}, and $N_{gas}/(N_x A_{ion})$ *Medical Physics* 15 (5):751-754, 1986.
4. "Dosimetry Quality Assurance in U.S. from the Experience of The Radiological Physics Center" W.F. Hanson, R. J. Shalek, and P. Kenedy Quality Assurance in Radiotherapy Physics , Proceedings of ACMP Symposium, p. 255-282,1991.
5. M. Peterson and R. Golden, *Radiology* 103:675 (1972)
6. W. H. Barnes, D. B. Hammond, G. G. Janik, " Beam Characteristics of the Clinac 2500 " Presented at Varian users Group Meeting (1983) (*Available from RPC*).

References

7. J.A. Purdy, W. B. Harms, and S. Fivozinsky, *Proceedings of the Fourth Annual Symposium on Computer Application in Medical Care* (Nov 1980).
8. D.O. Findley, B. W. Forell, and P.S. Wong, *Medical Physics*, 14: 270 (1987).
9. D.S. Followill, D.S. Davis, and W. F. Hanson " Standard Wedge Transmission for Varian, Siemens, Philips, and AECL Accelerators," *Medical Physics* 6:1076 (1997).
10. "Remote monitoring Program for Dosimetry Data and Patient Dose Calculations", Medical Physics, Vol. 25, No. 7, 1998.
11. "Analysis of Radiological Physics Center Remote Monitor Tools Program Data", Physics, Vol. 26, No. 6, 1999.
12. British Journal of Radiology Supplement 17. The British Institute of Radiology 1983