

Analysis Of Radiological Physics Center Remote Tools Program Data

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Abstract

The RPC is developing various remote monitoring tools to identify, evaluate, and resolve systematic discrepancies in institution's dosimetry data and dose calculation algorithms. The objective of the program is to provide a baseline quality audit, short of an on-site visit, to all institutions participating in NCI-funded cooperative clinical trial groups. For the conventional external beam radiotherapy the program developed complements the TLD remote monitoring program for machine output that the RPC has been operating since 1972. In conjunction with the mailed TLD, the program monitors machine output, dosimetry data in use, and treatment planning algorithms. The TG-21 factors used in output calibration calculations are reviewed; dosimetry data are compared to RPC "standard data" for output, percentage depth dose, wedge, and off-axis factors; and treatment time calculation for two benchmark cases are verified against RPC data and calculation techniques. This program identifies discrepancies comparable to those discovered during an on-site evaluation, with the major discrepancies focused on wedge transmission and photon depth dose.

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Introduction

The implementation of an off-site dosimetry review program during the last two years is allowing the RPC to perform a more comprehensive review of more Institutions than can be reviewed by on-site visits alone. The primary objectives of the program is to verify that institution dosimetry data & treatment planning algorithms are consistent with RPC technique & standard dosimetry data. Secondary objectives include

1. The identification and resolution of systematic discrepancies in dosimetry data, dose calculation algorithms, and calibration procedures.
2. The identification of institutions for on-site visit prioritization.
3. Supplement the collection of data on equipment and personnel.
4. Help in the identification of machine makes & models for which the RPC has no standard data.

The items reviewed are: photon and electron beams, clinical dosimetry via benchmark cases, calibration of dosimetry (TG21/TG51) equipment, QA procedures, and Brachytherapy. The program collects data on cone ratios but does not yet have a technique to review them. The institution's data and benchmark cases are compared against RPC "standard data" and calculative techniques. The review of 75 institution 235 photon beams and associated electron beams has been completed and a second review by other RPC physicists is in process. A concise summary report has been developed and several institution reviewed has been prioritized for on-site review visits. Four on-site review visits have been completed. The following is an overview of the off-site review program.

Materials and Methods

Institutions are asked to complete information forms, submit copies of dosimetry data, and calculate machine set for several benchmark treatments. The Six Questionnaires sent 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.

Evaluation Criteria

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

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

Resolution of Discrepancies

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

Materials and Methods

The following evaluation tools are used to revise institution' dosimetry:

Photon Beams:

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

RPC "Standard Data"

- ✦ The RPC has not made dosimetry measurements on the specific therapy units at the institutions reviewed. However measurements by the RPC on at least 5 units of the same make and model of LINACS have been made for which a set of "Standards" dosimetry data have been determined.
- ✦ The RPC have measured data on 1305 linear accelerators:
 - 125 Linacs of different make/models/energies
 - 49 Linacs with more than 5 data sets
 - 30 Linacs with more than 10 data sets
- ✦ Analysis of RPC measured data indicates that machines of the same make, model and energy have the same radiation characteristics
- ✦ Data for Linacs with more than 5 sets are averaged to yield 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)
- ✦ Pion values

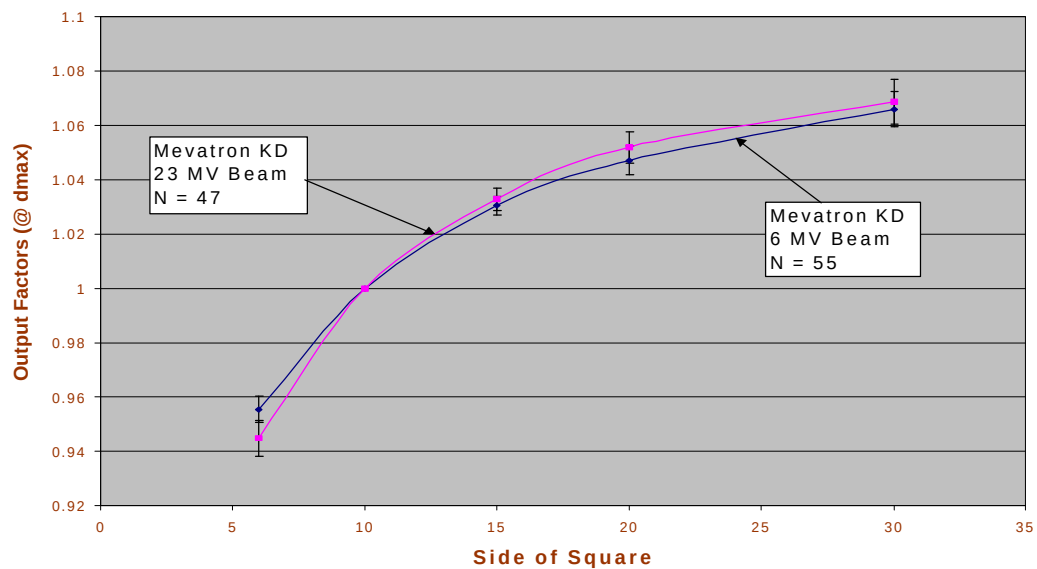
Standard Data for Electron Beams Include:

- ✦ Depth dose data
- ✦ Extended dist. Factor
- ✦ Pion values

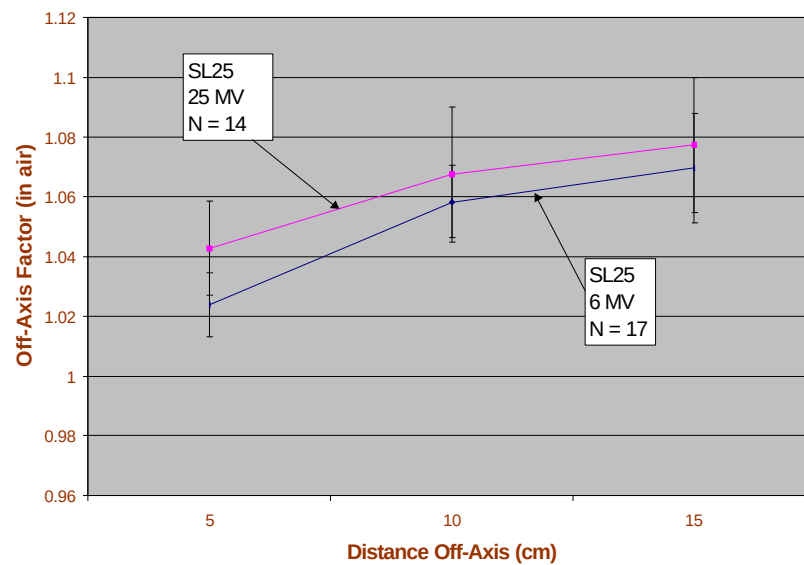
✦ Brachytherapy

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

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.



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



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

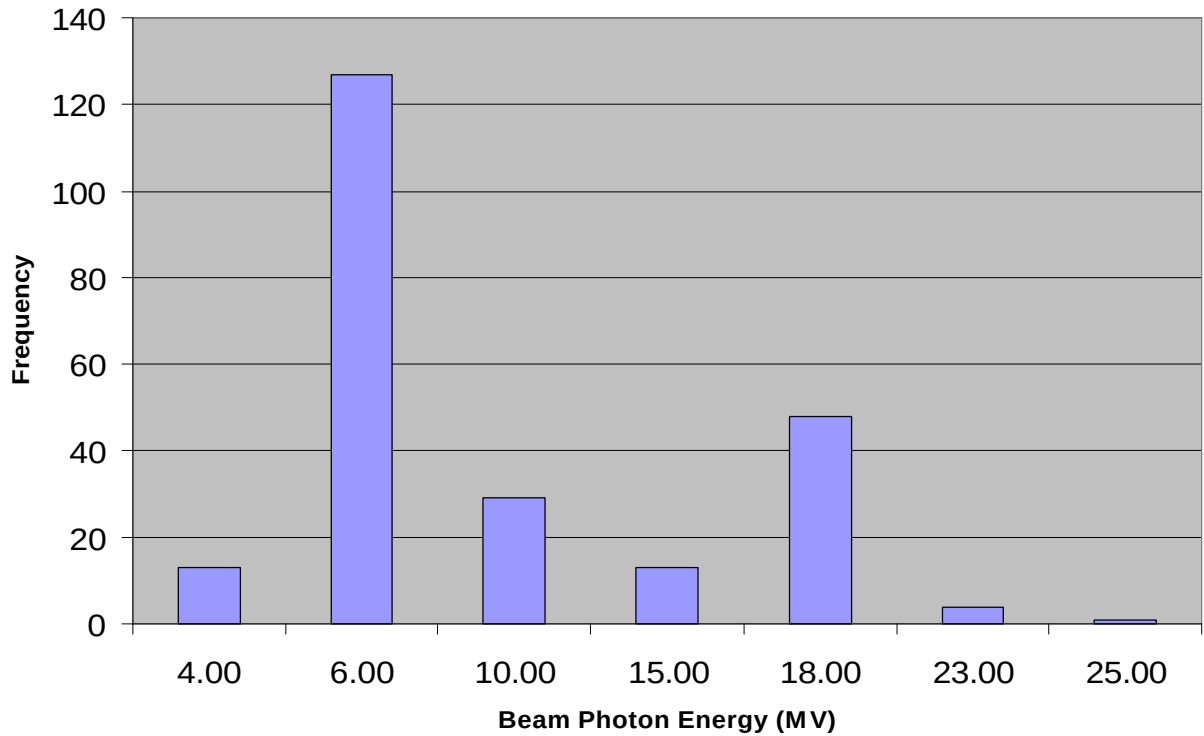
Field Size (cm x cm)	Depth (cm)	N	Mean	Standard Deviation	BJR17 21 MV
6 x 6	7	59	0.907	0.007	0.898
	10	72	0.799	0.006	0.796
	15	72	0.646	0.005	0.640
	20	72	0.522	0.004	0.515
10 x 10	7	59	0.900	0.007	0.890
	10	72	0.798	0.006	0.789
	15	72	0.651	0.005	0.640
	20	72	0.531	0.004	0.523
20 x 20	7	59	0.887	0.009	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

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

Results

Data collected from 75 institutions show the following distribution of Photon Beams energies regardless of machine model and make.



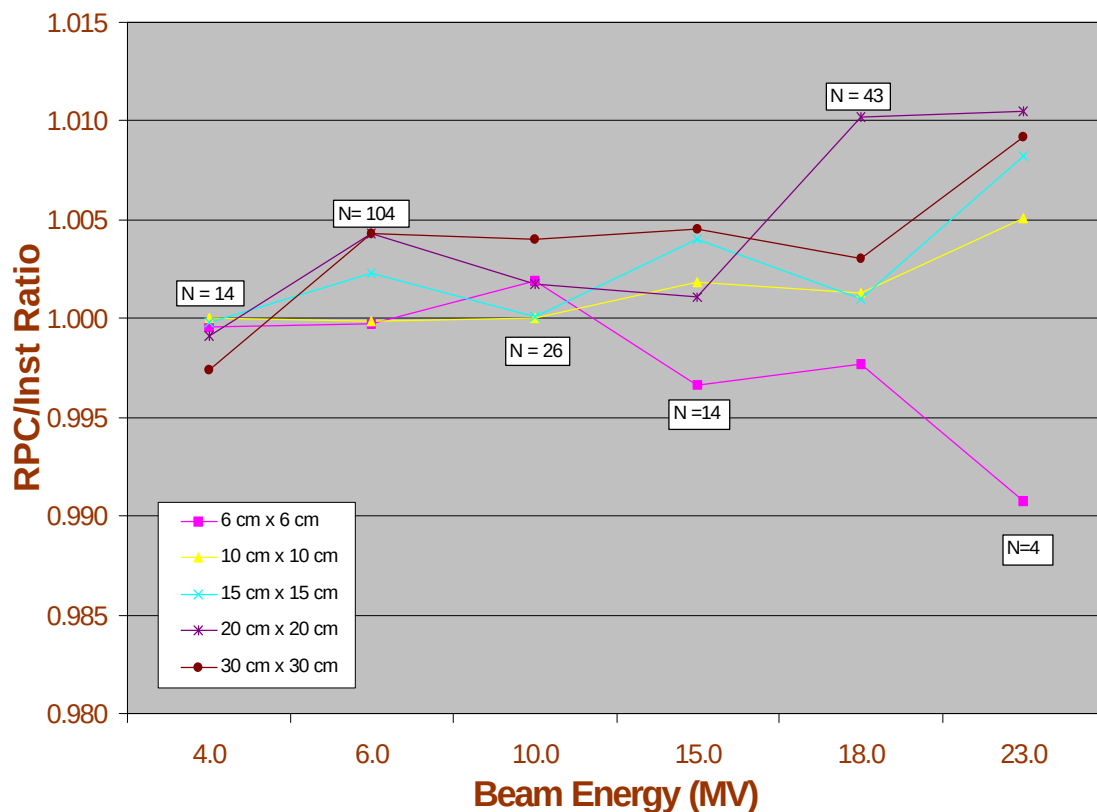
Data collected from institutions show the following distribution of Photon Beams by manufacturer and single or multi modality LINACS.

Machine	Modality	# of Machines	# of Models	# of Beams
Cobalt-60	Single	3	3	5
Varian	Single	9	8	47
	Multi	14	3	121
Seamen	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

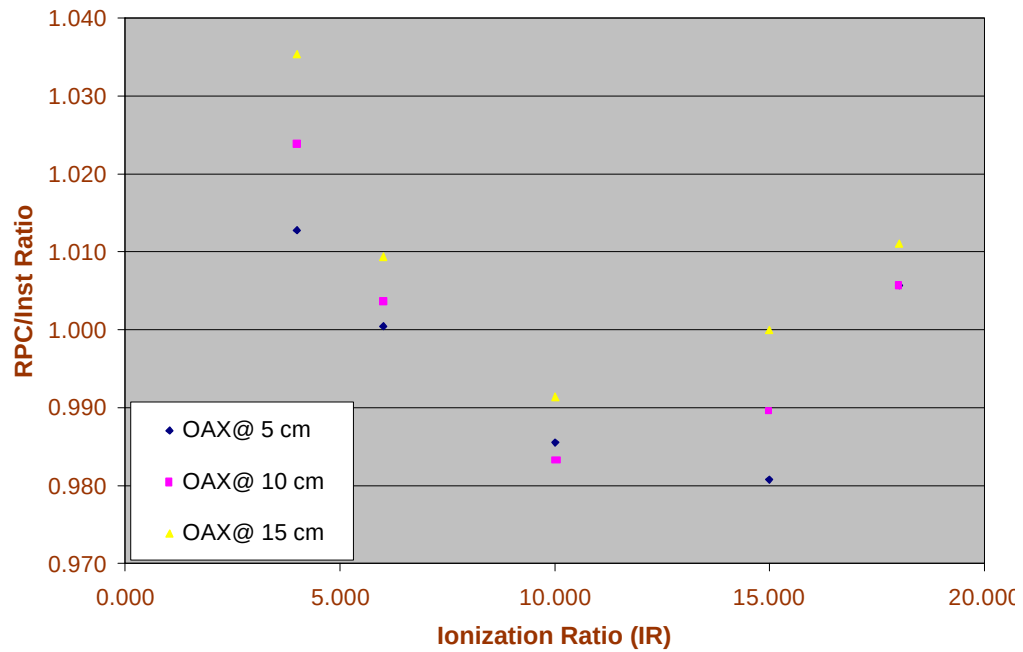
This Table summarizes the analysis of the off-site dosimetry review. The major discrepancies occur for wedge transmission (field size & depth dependence), Photon depth dose (@ deep depths, low energies), and off-axis factors. The depth dose discrepancies are higher than expected.

Parameter (RPC/Inst. Ratio)	RPC Paper Review Acceptance Criterion	% Beams outside the criteria
TG-21 Factors	$\pm 1\%$	6.9%
Output Factors	$\pm 2\%$	4.2%
%DD	$\pm 2\%$	13.0%
Wedge Factors	$\pm 3\%$	11.2%
Off-Axis Factors	$\pm 2\%$	13.6%

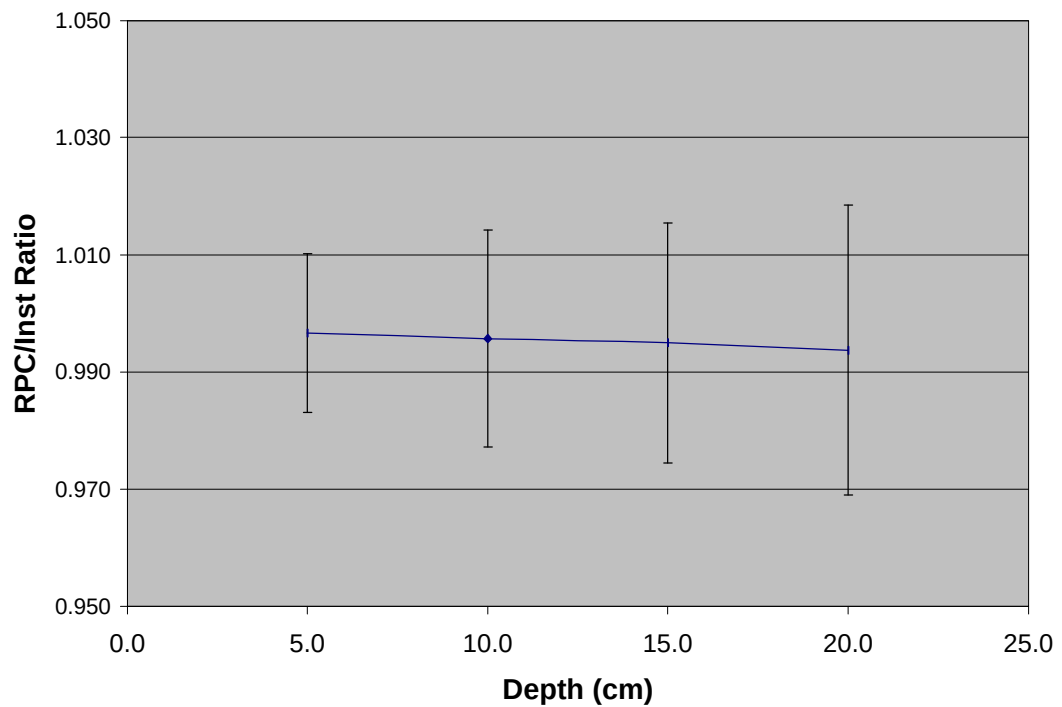
This graph shows the mean output factor's RPC/Inst ratio for different field sizes and photon energies. The total number of beams is 205.



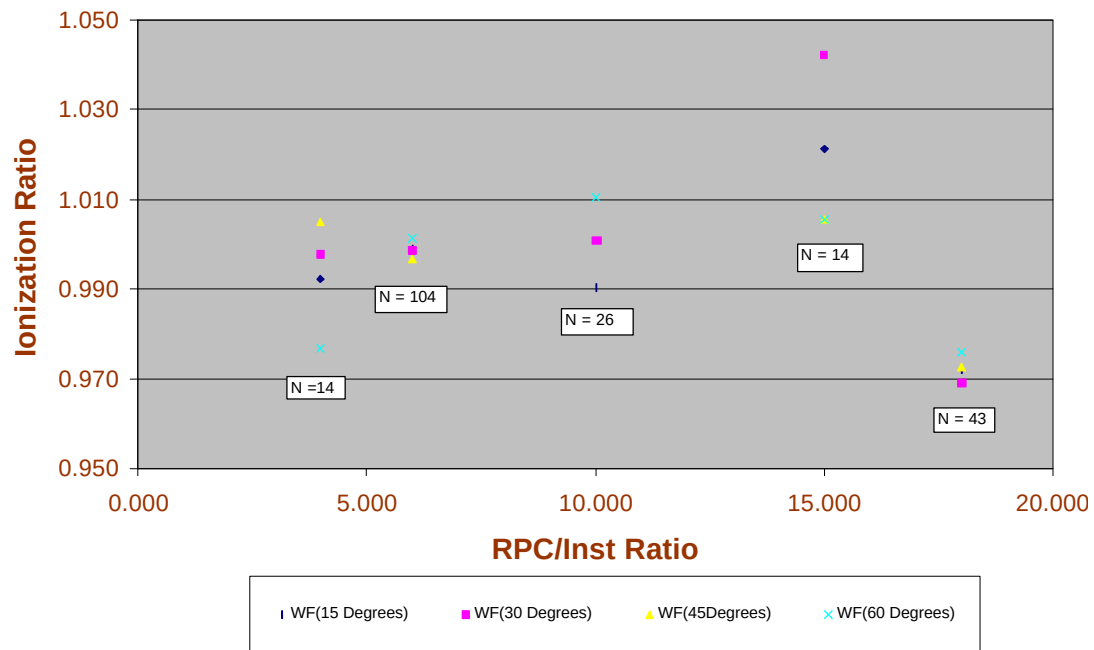
Mean OAX Factor's RPC/Inst Ratio @ different OAX distances vs. Photon Energy (@ 4, 10, & 15 MV, there is limited data: 3,2,3 beams respectively).



Mean Percentage Depth Dose Factor's RPC/Inst ratio plotted vs. Depth regardless of beam energy or field size. Note that as expected the discrepancies increases slightly with increased depth.



Mean Wedge Factor's RPC/Inst Ratio Regardless of Field Size or Depth vs. Beam Energy for photon beams analyzed.

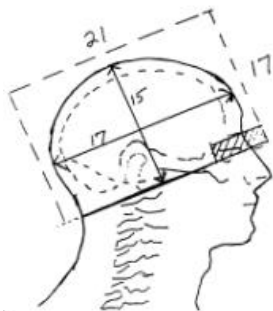


Benchmark Cases

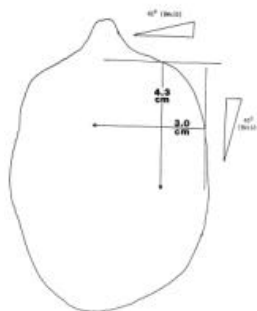
Cases used to test the Institution's Treatment Planning Computers

- 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)



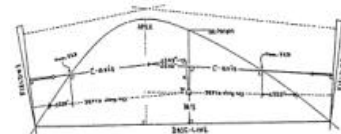
(2) Wedge pair
(test WF)



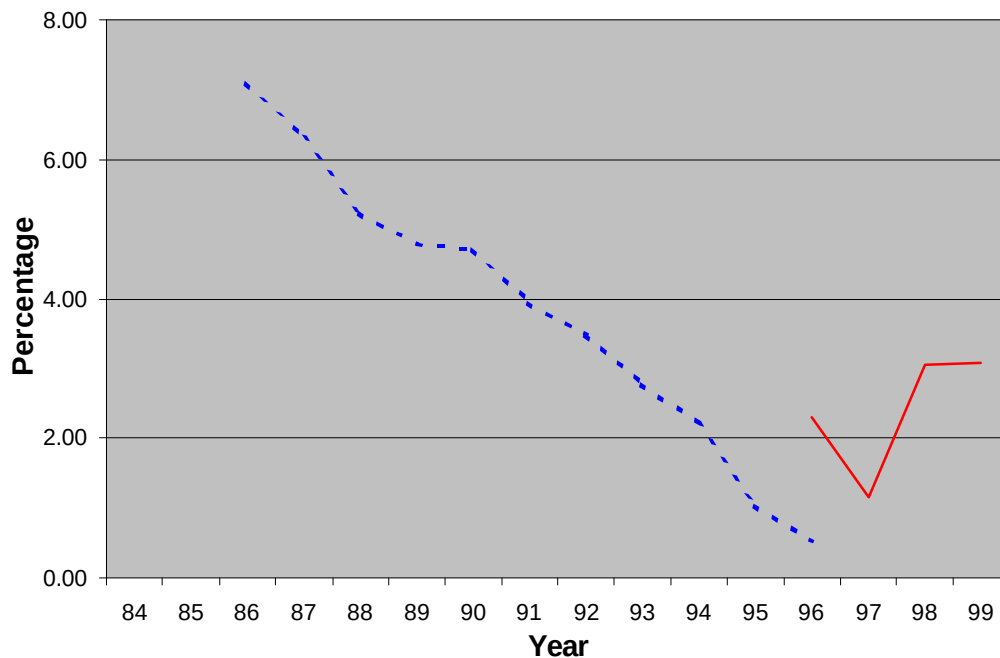
(3) Lung
(IRREG.)



(4) Breast
(Breast Problems.)



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



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	$\pm 3\%$	10.6%
Lung on CAX	$\pm 3\%$	0.0%
Lung Lower Medstim.	$\pm 3\%$	7.2%
Lung Supraclav.	$\pm 3\%$	9.6%

Problems and Shortcomings

- RPC lacks "standard data" for some make and models of Linacs.
- RPC lacks data on electron cone ratios.
- No RPC standard developed against which to compare Brachytherapy data.

Conclusions

- The evaluation of institution's dosimetry data in conjunction with their history of TLD results and the RPC "standard data" allows the RPC to identify institutions with potential systematic dosimetry problems.
- Using these new remote tools the RPC hope to be able to monitor more institutions participating in NCI cooperative groups.

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