AAPM Task Group 178
Gamma Stereotactic Radiosurgery Dosimetry and Quality Assurance

AAPM 58th Annual Meeting
August, 2016

Steven J. Goetsch, Ph.D., FAAPM

San Diego Gamma Knife Center and
Professor, Radiological Technologies University VT

Disclosure: the author is a part-time consultant to Elekta, Inc.

AAPM Task Group 178

Steve Goetsch, Chair	San Diego Gamma Knife Ctr
Paola Alvarez	M.D. Anderson
Greg Bednarz	University of Pittsburgh
Larry De Werd	Univ. of Wisconsin ADCL
Bob Drzymala	Washington University
David Larson	UCSF Medical Center
Lijun Ma	UCSF Medical Center
Sheridan Meltsner	
Gennady Neyman	Cleveland Clinic
Josef Novotny	University of Pittsburgh
Mark Rivard	
Arjun Sahgal	Sunnybrooke Med Center
Almon Shiu	USC Medical Center

68-100% centers reporting
1991 reflects cumulative numbers

AAPM Task Group 178
Consultants

Keith Kunugi	University of Wisconsin ADCL
Jan Seuntjens	McGill University Med Center
Jonas Johansson	Elekta Corporation

Calibration of GSR Units

- No current external beam protocols apply to certain devices
- Gamma Knife, Tomotherapy, Cyberknife and Viewray are “**noncompliant**” with TG-51 Absorbed Dose in Water protocol
- What’s a poor physicist to do?
- Improvise!!

TG21 and TG 51: Presumes Point Source Diverging to $10x10cm^2$ field at 100cm

- **Cyberknife** comes closest: 6cm diameter field size at 80cm. New M6 gives up to 10 by $12cm^2$ at 80cm
- **Tomotherapy**: up to 5 by $40cm^2$ at 85cm
- **Viewray**: 105cm isocenter (rotational) up to $27.3cm^2$
- **Gamma Knife Perfexion**: 192 sources converging on 4, 8 or 16mm diameter field at roughly 40cm

Medical Physics Letter

A new formalism for reference dosimetry of small and nonstandard fields

R. Alfonso
International Atomic Energy Agency, A-1400 Vienna, Austria and Instituto Nacional de Oncologia y Radiobiologia, CP 10400 La Habana, Cuba

P. Andreo
International Atomic Energy Agency, A-1400 Vienna, Austria and University of Stockholm-Karolinska Institutet, SE-17176 Stockholm, Sweden

R. Capote
International Atomic Energy Agency, A-1400 Vienna, Austria

M. Saiful Huq
University of Pittsburgh Cancer Institute, Pittsburgh, Pennsylvania 15232

W. Kilby
Accuray Inc., Sunnyvale, California 94089

P. Kjäll
Elekta Instrument AB, SE-10393 Stockholm, Sweden

T. R. Mackie
Department of Medical Physics, University of Wisconsin, Madison, Wisconsin 53706

H. Palmans[a)]
National Physical Laboratory, Teddington, Middx TW11 0LW, United Kingdom and Slovenský Metrologický Ústav, SK-84255 Bratislava, Slovakia

K. Rosser
Royal Marsden NHS Foundation Trust, Sutton, Surrey SM2 5PT, United Kingdom

J. Seuntjens
Medical Physics, McGill University, Montreal, Québec H3G 1A4, Canada

W. Ullrich
BrainLAB AG, D-85622 Feldkirchen, Germany

S. Vatnitsky
International Atomic Energy Agency, A-1400 Vienna, Austria

(Received 2 June 2008; revised 2 October 2008; accepted for publication 2 October 2008; published 28 October 2008)

Letter to the Editor Alfonso et al, Med Phys 2008

- Authors laid out a path by which a unique geometry “noncompliant” w TG-51 Absorbed Dose Protocol could be adapted to comply
- Defined two fields: f_{ref} and f_{fmsr}
- The **first field** f_{ref} is “standard” field size: 10 by 10cm^2
- The **second field** f_{fmsr} is a “machine-specific reference field”

Background: Dose Calibration Protocols

Ionization chamber calibrated in water

	IAEA TRS-398 (2000)	AAPM TG-51 (1999)	IAEA Working Group (Alfonso 2008) *
Parameters	Simple measured	Simple measured	Simple measured + Monte Carlo (MC) generated
Advantages	• Simple to use • Likely to achieve consistent results across different institutions		• Machine-specific correction factor • Accounts for different ionization chambers and phantom types
Disadvantages	Designed for use with linear accelerators: • 10 x 10 cm2 field • Water phantom		MC parameters must be generated for each ionization chamber and phantom combination

*Med. Phys. 35, 5179-5186 (2008)

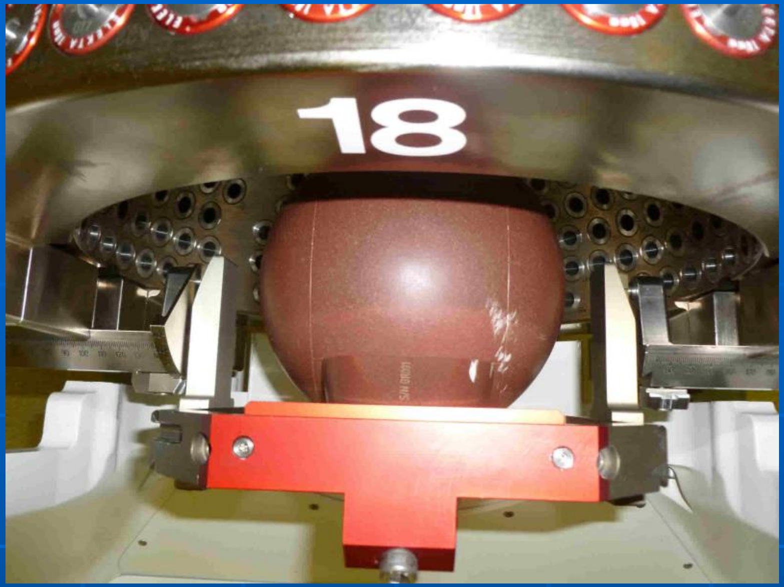
Equipment and Measurements

Ionization Chambers	Collecting Volume
PTW TN31010 (PTW)	0.125 cc
Standard Imaging Exradin A16 (Ex)	0.007 cc
Electrometer:	Standard Imaging Max 4000

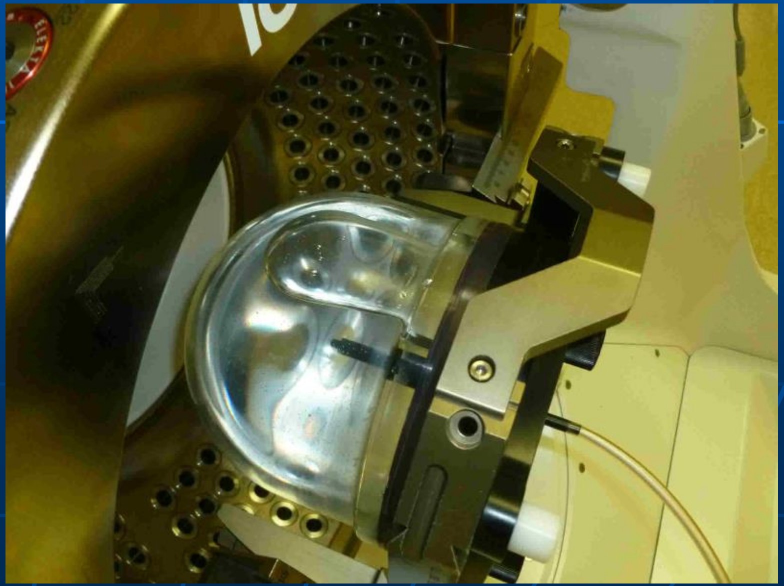
Phantom One:

Elekta (gray) ABS plastic 16cm diameter solid phantom

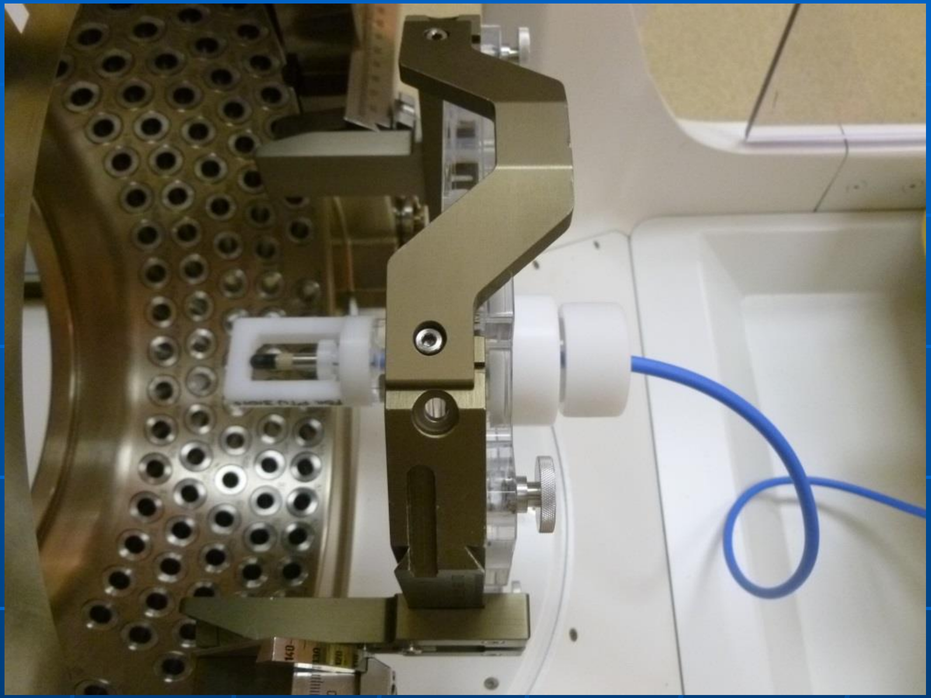
Phantom Two: Elekta Solid Water 16cm diameter phantom



Phantom Three: Phantom Laboratories Liquid Water 16cm diameter hemispherical phantom



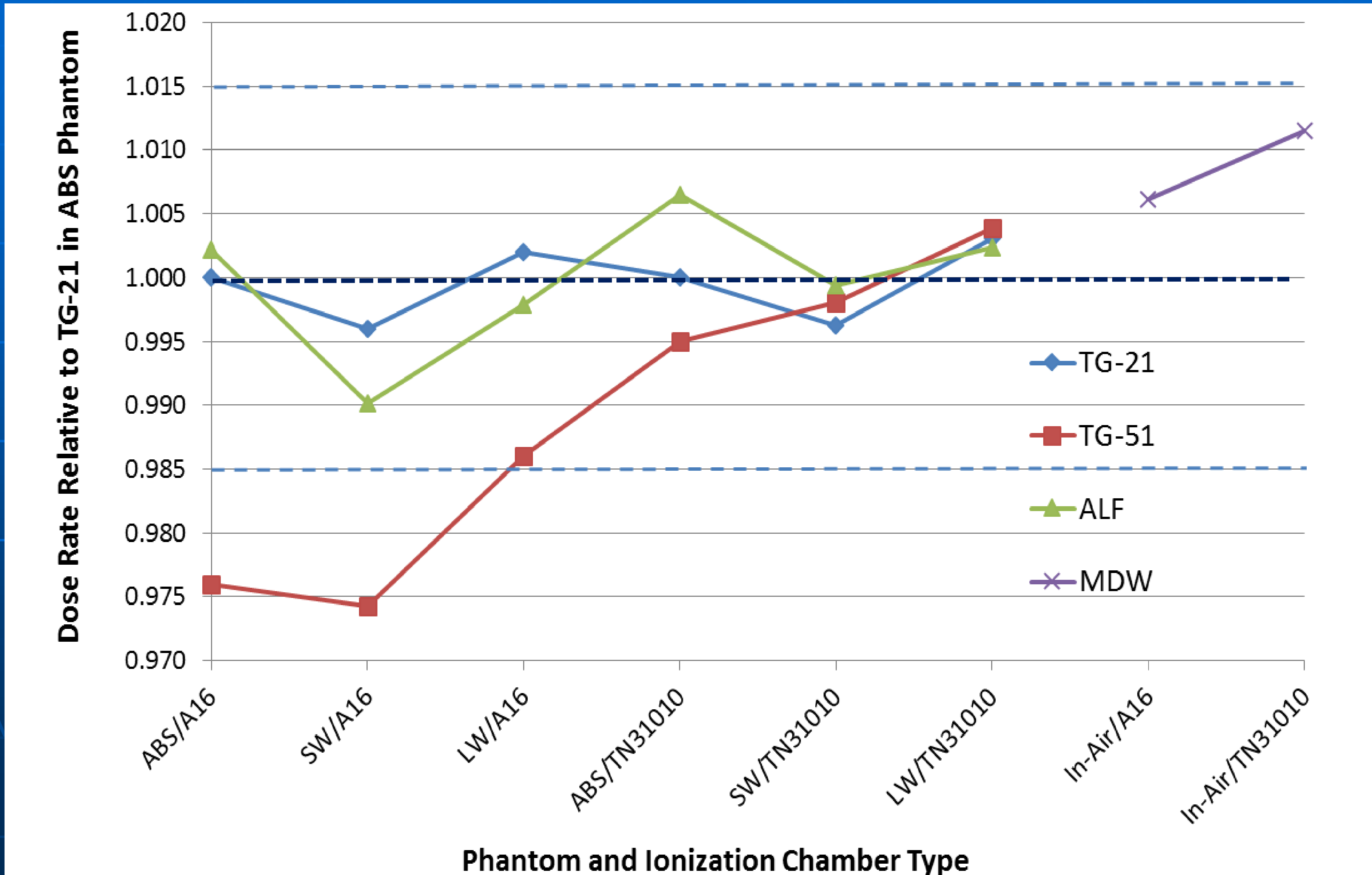
Phantom Four: Standard Imaging In-air phantom



Summary of Measurements

Phantom	Chamber model	Protocol/formalism
ABS	A16	TG-21, ALF
ABS	TN31010	TG-21, ALF
SW	A16	TG-21, TG-51, ALF
SW	TN31010	TG-21, TG-51, ALF
LW	A16	TG-21, TG-51, ALF
LW	TN31010	TG-21, TG-51, ALF
IA	A16	MDW
IA	TN31010	MDW

Results Averaged over all Institutions Sorted by Dosimetry Protocol/Formalism



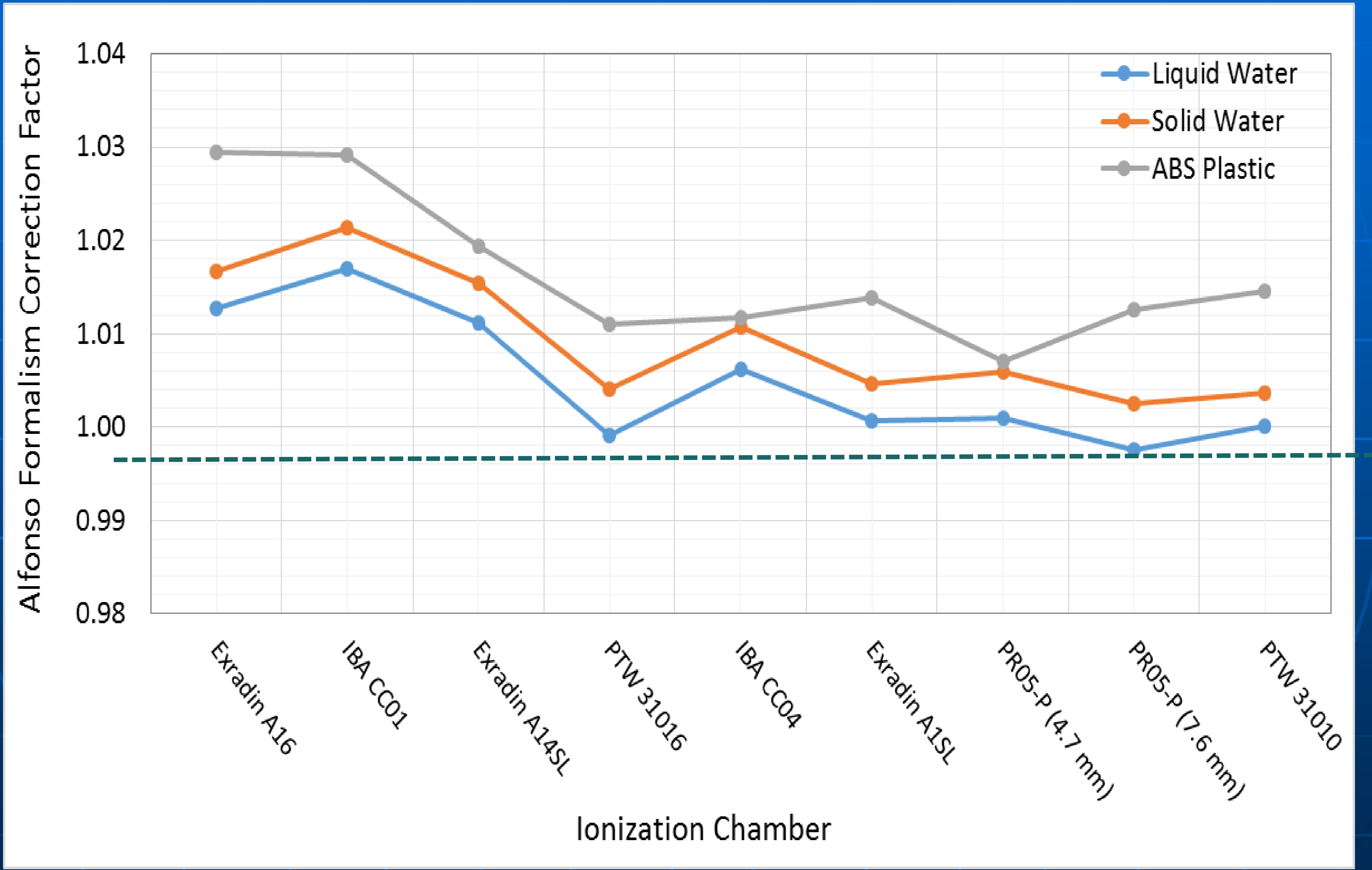
IAEA (Alfonso) Formalism $k_{Q_{mrs},Q}^{f_{mrs},f_{ref}}$ factors from Elekta Phys. Rep.*

Chamber type	PFX			LGKC		
	SW	ABS	H_2O	SW	ABS	H_2O
PTW 31010	1.0037	1.0146	1.0001	0.9958	0.9990	0.9924
PTW 31016	1.0040	1.0110	0.9991	1.0014	1.0025	0.9964
Exradin A1SL	1.0046	1.0138	1.0006	1.0009	1.0014	0.9967
Exradin A14SL	1.0154	1.0194	1.0112	1.0116	1.0060	1.0058
Exradin A16	1.0167	1.0295	1.0127	1.0163	1.0217	1.0104
IBA CC01	1.0213	1.0292	1.0169	1.0203	1.0208	1.0157
IBA CC04	1.0107	1.0117	1.0062	1.0086	1.0049	1.0040
PR05-P (4.7 mm)	1.0059	1.0070	1.0010	1.0007	0.9960	0.9951
PR05-P (7.6 mm)	1.0025	1.0126	0.9976	0.9885	0.9972	0.9844

Take a closer look…

*Johansson and Gorka, Elekta Physics Report: Reference No. SSM 2010/2201, Project nr 4017003-006)

Alfonso $k_{Q_{mrs},Q}^{f_{mrs},f_{ref}}$ factors for PFX from Elekta Phys. Rep.



IAEA (Alfonso) formalism $k_{Q_{mrs},Q}^{f_{mrs},f_{ref}}$ Factors for PFX

From previous slide: Average values for ionization chambers with collecting volume $\geq$ 0.05 cm^3

Liquid Water:	1.000 ± 0.0015
Solid Water:	1.004 ± 0.0014
ABS Plastic:	1.012 ± 0.0034

A round-robin gamma stereotactic radiosurgery dosimetry interinstitution comparison of calibration protocols

R. E. Drzymala[a)]
Department of Radiation Oncology, Washington University, St. Louis, Missouri 63110

P. E. Alvarez
Imaging and Radiation Oncology Core Houston, UT MD Anderson Cancer Center, Houston, Texas 77030

G. Bednarz
Radiation Oncology Department, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania 15232

J. D. Bourland
Department of Radiation Oncology, Wake Forest University, Winston-Salem, North Carolina 27157

L. A. DeWerd
Department of Medical Physics, University of Wisconsin-Madison, Madison, Wisconsin 53705

L. Ma
Department of Radiation Oncology, University California San Francisco, San Francisco, California 94143

S. G. Meltsner
Department of Radiation Oncology, Duke University Medical Center, Durham, North Carolina 27710

G. Neyman
Department of Radiation Oncology, The Cleveland Clinic Foundation, Cleveland, Ohio 44195

J. Novotny, Jr.
Medical Physics Department, Hospital Na Homolce, Prague 15030, Czech Republic

P. L. Petti
Gamma Knife Center, Washington Hospital Healthcare System, Fremont, California 94538

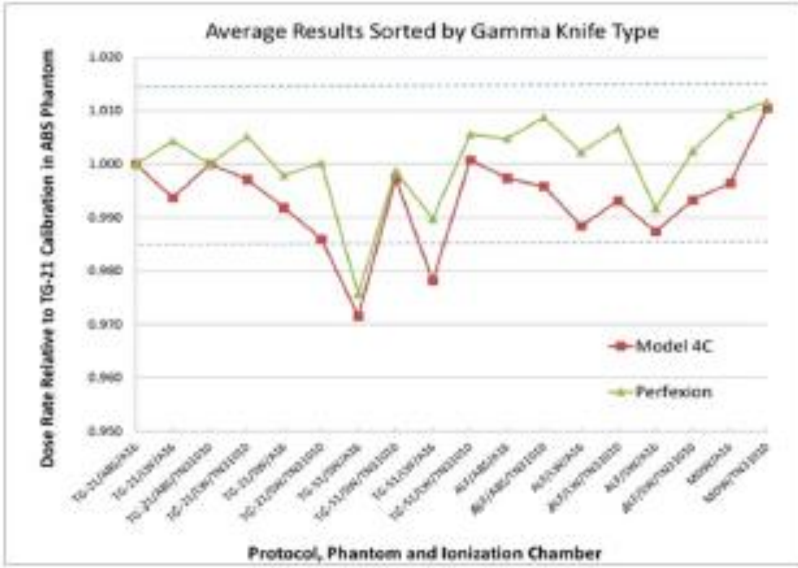
M. J. Rivard
Department of Radiation Oncology, Tufts University School of Medicine, Boston, Massachusetts 02111

A. S. Shiu
Department of Radiation Oncology, University of Southern California, Los Angeles, California 90033

S. J. Goetsch
San Diego Medical Physics, Inc., La Jolla, California 92037

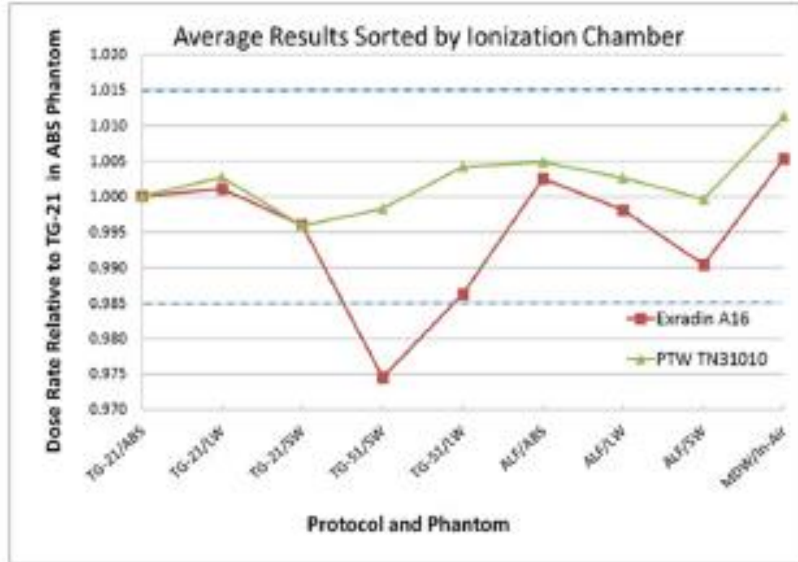
(Received 6 December 2014; revised 2 October 2015; accepted for publication 10 October 2015; published 30 October 2015)

Drzymala et al, Med Phys 42 (11) November, 2015



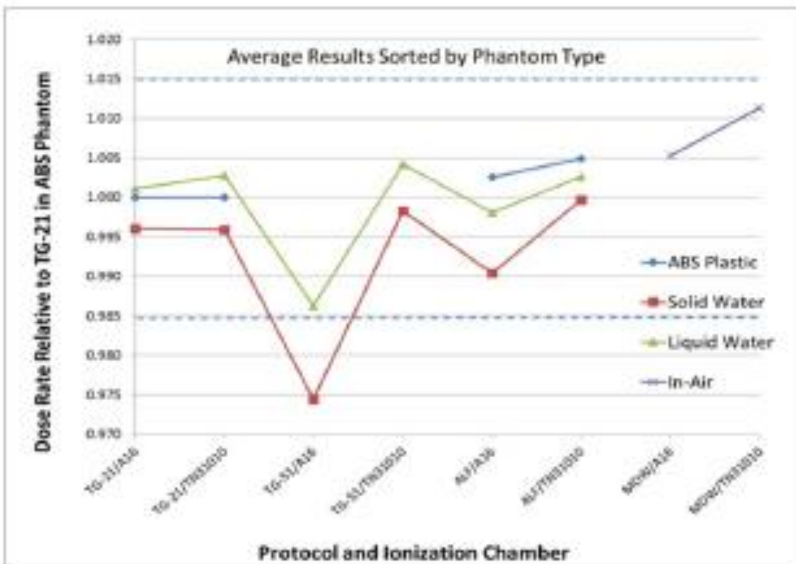
Average Results Sorted by Gamma Knife Type
Dose Rate Relative to TG-21 Calibration in ABS Phantom
Model 4C
Perfexion
Protocol, Phantom and Ionization Chamber

(a)



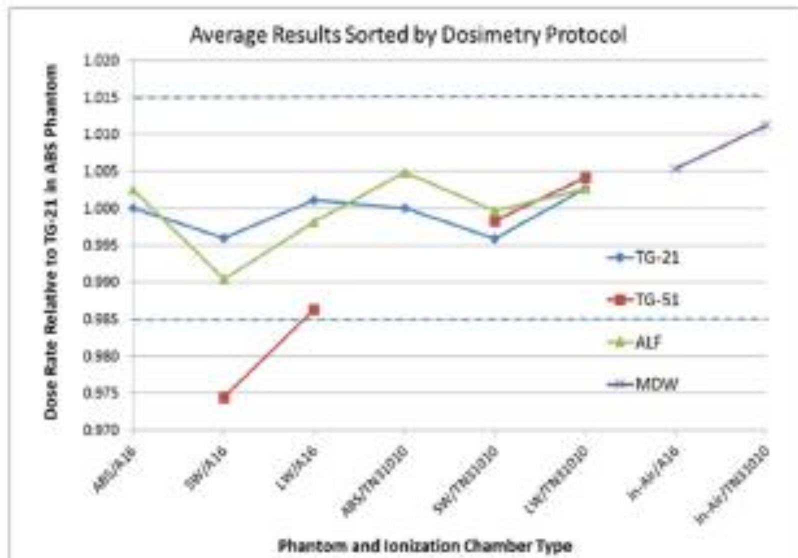
Average Results Sorted by Ionization Chamber
Dose Rate Relative to TG-21 in ABS Phantom
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
0.975
0.970
Exradin A16
PTW TN31010
TG-21/ABS
TG-21/LW
TG-21/SW
TG-51/SW
TG-51/LW
ALF/ABS
ALF/LW
ALF/SW
MDW/In-Air
Protocol and Phantom

(b)



Average Results Sorted by Phantom Type
Dose Rate Relative to TG-21 in ABS Phantom
ABS Plastic
Solid Water
Liquid Water
In-Air
Protocol and Ionization Chamber

(c)



Average Results Sorted by Dosimetry Protocol
Dose Rate Relative to TG-21 in ABS Phantom
1.020
1.015
1.010
1.005
1.000
0.995
0.990
0.985
0.980
0.975
0.970
TG-21
TG-51
ALF
MDW
Phantom and Ionization Chamber Type

(d)

Conclusions

- Four different procedures were carried out on four different phantoms, utilizing two small volume ion chambers and four protocols
- All results were quite consistent
- TG-51 modified by factors (announced but not yet published) following the formalism of Alfonso et al, yielded the overall best results
- This procedure uses the Elekta ABS phantom supplied w every Elekta Gamma Knife in the world

References

Elekta white papers (available on request):

1. Accuracy of co-registration of planning images with Cone Beam CT images
2. Automatic positional delivery correction using a stereotactic CBCT in Leksell Gamma Knife Icon™
3. Design and performance characteristics of a Cone Beam CT system for Leksell Gamma Knife Icon ™
4. Geometric quality assurance for Leksell Gamma Knife Icon™
5. Automatic positional delivery correction using a stereotactic CBCT in Leksell Gamma Knife Icon™
6. Li et al "Impact of Immobilization on Intrafraction Motion for Dedicated Cobalt Radiosurgery Unit Using Cone Beam Computed Tomography" Int J Rad Onc Biol Phys Sep 2014 (abstract)