



Delta^{4PT}

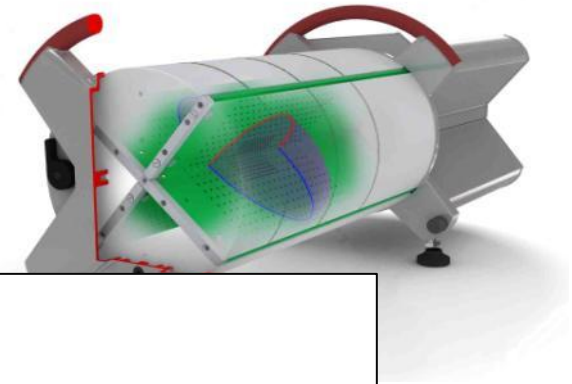
- Instantly approve plans based on clinical relevance
- Verify plans with real measurements
- Customized acceptance criteria

Delta^{4PT} 3D and DVH

Professional + Anatomy Option

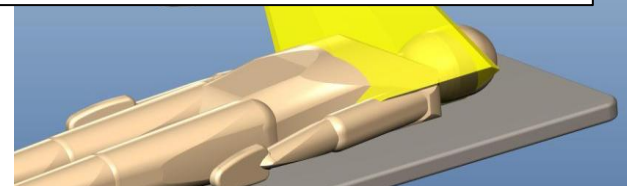
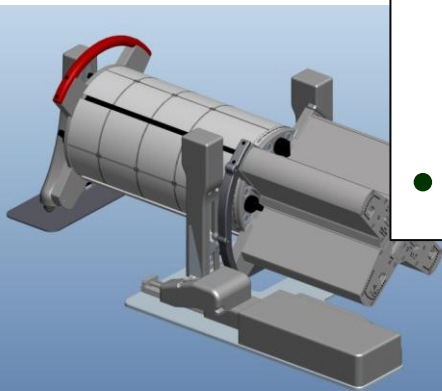
Thomas Matzen

The Growing Delta⁴ Family



Delta⁴PT

- Misst dort, wo's drauf ankommt
- Dosis per Organ...
 - im Phantom
 - im Patienten
- QS: klinische Relevanz (seit 2007!)



Qualitätssicherung?

“Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors”¹

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors¹

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(Received 19 September 2010; revised 28 December 2010; accepted for publication 30 December 2010;
published 31 January 2011)

Purpose: The purpose of this work is to determine the statistical correlation between per-beam, planar IMRT QA passing rates and several clinically relevant, anatomy-based dose errors for per-beam IMRT QA. The intent is to assess the predictive power of a common conventional IMRT QA performance metric, the Gamma passing rate, by including four types of dose errors in QA.

Methods: Ninety-six unique data sets were created by including four types of dose errors in QA: (1) a moderate correlation between IMRT QA passing rates and step-and-shoot delivery. The error was called “false negative.” The results also show numerous instances of high IMRT QA passing rates, when per-beam IMRT QA passing rates do not imply large errors in anatomy dose metrics. In some of the cases where the correlation coefficient was high, predictive power of planar IMRT QA passing rates, i.e., in some of the cases did high IMRT QA Gamma passing rates predict low errors in anatomy dose metrics or vice versa.

Results: Analysis of clinical metrics (paired mean doses, spinal cord max and D1cc, CTV D95, and mean rectum vs IMRT QA Gamma analysis (D95 min, D10, D1)) showed that in all cases, there were only weak to moderate correlations (range of Pearson's r -values = -0.295 to 0.653). Moreover, the moderate correlations usually had positive Pearson's r -values (i.e., clinically relevant metric increased with increasing IMRT QA passing rates), indicating that some of the biggest differences occurred in the cases of high IMRT QA passing rates, which may imply that anatomy-based dose differences occurred in the cases of high IMRT QA passing rates, when per-beam IMRT QA passing rates do not imply large errors in anatomy dose metrics. In some of the cases where the correlation coefficient was high, predictive power of planar IMRT QA passing rates, i.e., in some of the cases did high IMRT QA Gamma passing rates predict low errors in anatomy dose metrics or vice versa.

Conclusions: There is a lack of correlation between conventional IMRT QA performance metrics (Gamma passing rates) and dose errors in anatomy, regardless of dataset. The most common acceptance criteria and published clinical level thresholds have insufficient, or at best, improve, predictive power for per-beam IMRT QA. © 2011 American Association of Physicists in Medicine.

DOI: 10.1118/1.3544467

Key words: IMRT QA, IMRT, quality assurance

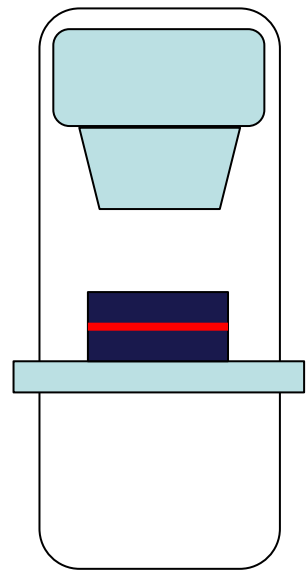
1. Published studies on IMRT QA acceptance criteria

1. INTRODUCTION

In modern radiation therapy, each patient treatment plan is customized and unique. In the case of intensity-modulated radiation therapy (IMRT), each treatment field can be highly complex and justify quality assurance (QA) to verify (1) the treatment planning system's (TPS) ability to calculate the dose accurately and (2) the delivery system's ability to deliver the dose accurately. A very common method of per-beam planar IMRT QA is to measure the dose to the phantom and compare to the TPS calculated dose in the same geometry, a method summarized in a recent published survey.¹

There have been many studies on suggested acceptance/ action levels for planar IMRT QA.²⁻⁴ Some of these studies have action levels on retrospective statistical analysis of the performance level/acceptance that have been achieved over many plans and IMRT beams.²⁻⁴ It has been suggested that meeting such action levels should be a requirement in order to take part in clinical trials.⁵ In a recent report of the AAPM Task Group 119 (Ref. 3) and, in fact, the other studies⁶⁻¹⁰ as well, the “95 min” criteria is common, employed as either the composite distance-to-a-gamma metric or the

1037 Med. Phys. 38 (2), February 2011 0047-2606/2011/38(2)/1037/\$30.00 © 2011 Am. Assoc. Phys. Med. 1037



¹Nelms *et al.*: Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med. Phys. 38 (2), February 2011

Qualitätsverunsicherung?

“Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose error”¹

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors¹

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(Received 19 September 2010; revised 28 December 2010; accepted for publication 30 December 2010;
published 31 January 2011)

Purpose: The purpose of this work is to determine the statistical correlation between per-beam, planar IMRT QA passing rates and several clinically relevant, anatomy-based dose errors for per-beam IMRT QA. The intent is to assess the predictive power of a common conventional IMRT QA performance metric, the Gamma passing rate, by inducing four types of dose errors in QA datasets. Ninety-six unique data sets were created by inducing four types of dose errors in QA datasets: (1) a moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653), (2) moderate to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653), (3) moderate to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653), (4) moderate to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653). The error dose distributions were used as “simulated measurements” for generating the IMRT QA dose plans and the resulting dose errors used as “simulated measurements” for generating the IMRT QA passing rates. The anatomy dose metric used to compare to the corresponding data calculated by the error-induced QA passing rates method to compare to the corresponding data calculated by the error-induced QA passing rates method.

The degree of the induced errors was varied to mimic IMRT QA passing rates that are commonly achieved using conventional methods.

Results: Analysis of clinical metrics (gamma pass rates, D1cc, CTV D95, etc.) showed that in all cases, there was a moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653). Moreover, when only weak to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653), moderate to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653), and moderate to moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653) were induced, the moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653) was observed. The moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653) was observed, which may indicate that moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653) is not a “false negative”. The results also show numerous instances of high Pearson's r values or cases where low IMRT QA passing rates do not imply large errors in anatomy dose metrics. In some of the cases where IMRT QA passing rates do not imply large errors in anatomy dose metrics, the cases where there is a moderate correlation anomaly (range of Pearson's r -values = -0.295 to 0.653) between IMRT QA passing rates and anatomy dose metrics or vice versa.

Conclusions: There is a lack of correlation between conventional IMRT QA performance metrics (Gamma passing rates) and dose errors in anatomy-based dose errors. The most common acceptance criteria and published clinical level thresholds have insufficient, or at best, improve, predictive power for per-beam IMRT QA. © 2011 American Association of Physicists in Medicine. DOI: 10.1118/1.3544467

Key words: IMRT QA, IMRT, quality assurance

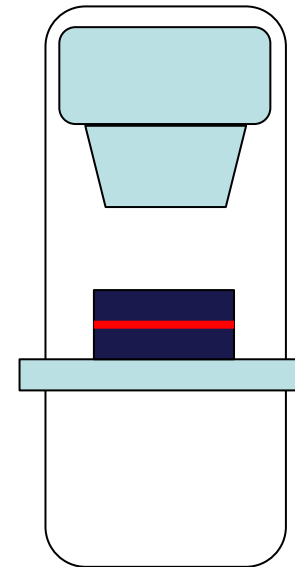
1. INTRODUCTION

In modern radiation therapy, each patient treatment plan is customized and unique. In the case of intensity-modulated radiation therapy (IMRT), each treatment field can be highly complex and justify quality assurance (QA) to verify (1) the treatment planning system's (TPS) ability to calculate the dose accurately and (2) the delivery system's ability to deliver the dose accurately. A very common method of per-beam planar IMRT QA is to measure the dose to the phantom and compare to the TPS calculated dose in the same geometry. A method summarized in a recent published survey¹

1.A. Published studies on IMRT QA acceptance criteria

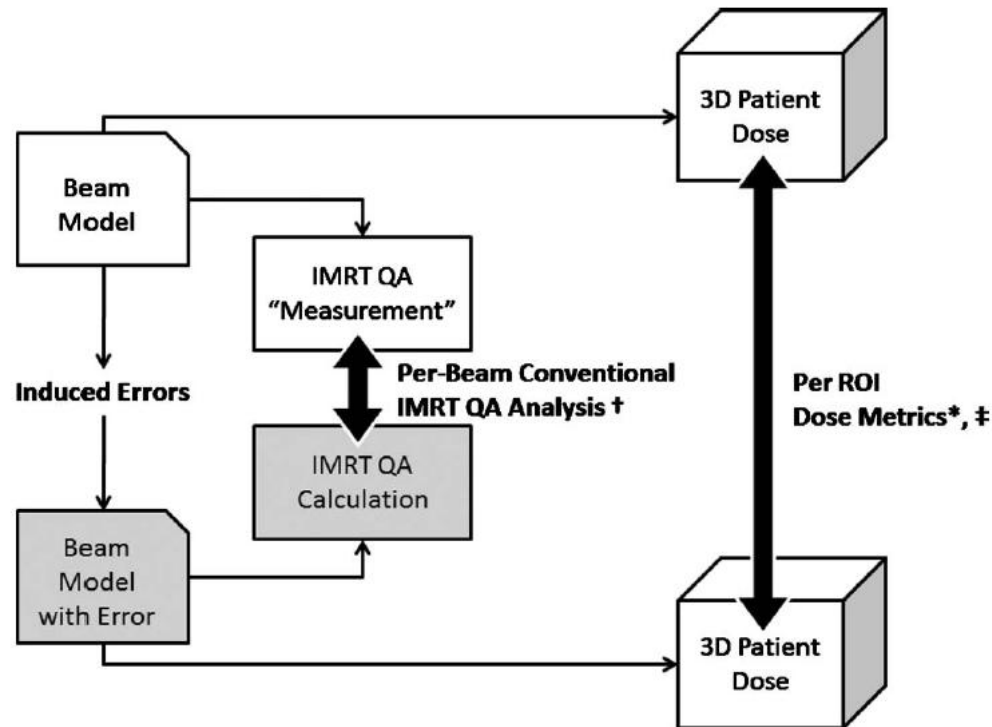
There have been many studies on suggested acceptance criteria for planar IMRT QA.²⁻⁶ Some of these studies have shown that per-beam IMRT QA passing rates do not predict clinically relevant patient dose errors. It has been suggested that many plans and IMRT beams² may not be as good as they appear. It has been suggested that having such action levels should be a requirement in order to help part in clinical trials.³ In a recent report of the AAPM Task Group 119 (Ref. 3) and, in fact, the other studies⁴⁻⁶ as well, the “95% min” criteria is common, employed as either the composite distance-to-a-gamma metric or the

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¹Nelms *et al.*: Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med. Phys. 38 (2), February 2011

Qualitätsverunsicherung?



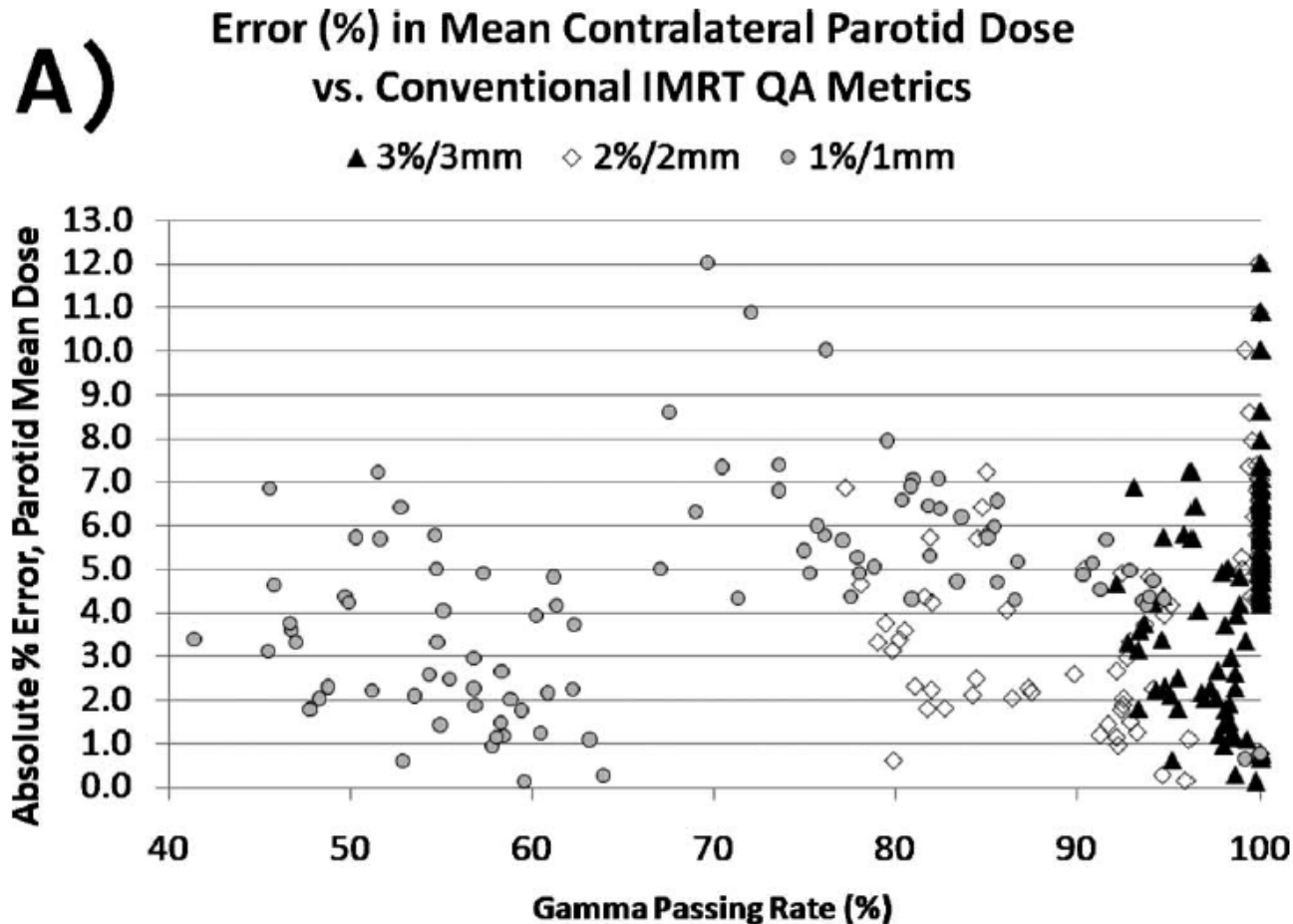
† Using full density (film equivalent) planes and high resolution (1 mm x 1 mm) pixels

* Max dose and D1cc (cord), mean dose (parotids, larynx), and D95 (CTV60)

‡ Comparison metrics were generated blind

Nelms *et al*: Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med. Phys. 38 (2), February 2011

Qualitätsverunsicherung?



Nelms *et al*: Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. *Med. Phys.* 38 (2), February 2011

Qualitätsverunsicherung?

“There is a lack of correlation between conventional IMRT QA performance metrics Gamma passing rates and dose differences in critical anatomic regions-of-interest.”¹

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors¹

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(Received 29 September 2010; revised 28 December 2010; accepted for publication 30 December 2010;
published 31 January 2011)

Purpose: The purpose of this work is to determine the statistical correlation between per-beam, planar IMRT QA passing rates and several clinically relevant, anatomy-based dose errors for IMRT QA. The intent is to assess the predictive power of a common, conventional IMRT QA performance metric, the Gamma passing rate per beam.

Methods: Ninety-six unique data sets were created by indexing four types of dose errors in 24 clinical head and neck IMRT plans, each planned with a 6 MV Varian 150-leaf MLC linear accelerator using a commercial treatment planning system and step-and-shoot delivery. The same-time beam/plant were used as “measured measurements” for generating the IMRT QA dose plans and the secondary dose metrics) to compare to the corresponding data calculated by the error-included planar QA metrics) to compare to the corresponding data calculated by the error-included planar QA metrics.

The degree of the statistical correlation between the secondary dose metrics and the planar QA metrics was assessed using conventional methods commonly achieved using conventional methods. **Results:** Analysis of clinical target (parotid) mean dose, spinal cord max and D_{10c}, CTV D₉₅, and larynx mean) vs IMRT QA Gamma analysis (95% pass, 2D, 1D) showed that in all cases, there were only weak to moderate correlations (range of Pearson's r -values = -0.263 to 0.653). Moreover, the moderate correlations actually had positive Pearson's r -values (i.e., clinically relevant metrics difference increased with increasing IMRT QA passing rate), indicating that some of the largest differences occurred in the case of high IMRT QA passing rates, which may be called “false negatives.” The results also show numerous instances of false positives or cases where low IMRT QA passing rates do not imply large errors in anatomy dose metrics. In some of the cases where there was correlation, a consistent with high predictive power of planar IMRT QA passing rates, the case was where correlation coefficient with high predictive power of planar IMRT QA passing rates, i.e., in some of the cases did high IMRT QA Gamma passing rates predict low errors in anatomy dose metrics or vice versa.

Conclusion: There is a lack of correlation between conventional IMRT QA performance metrics (Gamma passing rate) and dose errors in anatomic regions-of-interest. The most common acceptance criteria used published across levels therefore have insufficient, or at least unproven, predictive power for per-beam IMRT QA. © 2011 American Association of Physicists in Medicine. [DOI: 10.1118/1.3544657]

Key words: IMRT QA, IMRT, quality assurance

1A. Published studies on IMRT QA acceptance criteria

1. INTRODUCTION

In modern radiation therapy, each patient treatment plan is customized and unique. In the case of intensity-modulated radiation therapy (IMRT), each treatment field can be highly complex and justify quality assurance (QA) to verify (1) the treatment planning system's (TPS) ability to calculate the dose accurately and (2) the delivery system's ability to deliver the dose accurately. A very common method of per-beam planar IMRT QA is to measure the dose to a flat phantom and compare to the TPS calculated dose in the same geometry. A method summarized in a recent published survey²

There have been many studies on suggested acceptance criteria levels for planar IMRT QA.³⁻¹¹ Some of these studies have shown that the acceptance criteria levels for IMRT QA are not as strict as those for conventional IMRT QA. It has been suggested that many plans and IMRT beams³⁻¹¹ have been achieved over the past few years. In a recent report of the AAPM meeting on IMRT QA, it was stated that “the other studies”¹² as they Group 119 (Ref. 5) and, in fact, the other studies¹³ as well, the “50% rule” criteria is common, employed as either the composite distance-to-agreement (DTA) metric or the

¹Nelms *et al.*: “Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med. Phys. 38 (2), February 2011”

Warum?

Lösung

Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors¹

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(Received 29 September 2010; revised 24 December 2010; accepted for publication 30 December 2010;
published 31 January 2011)

Purpose: The purpose of this work is to determine the statistical correlation between per-beam, planar IMRT QA passing rates and several clinically relevant, anatomy-based dose errors for per-beam IMRT QA. The intent is to assess the predictive power of a common conventional IMRT QA performance metric, the Omlux passing rate per beam.

Methods: Ninety-six unique data sets were created by inducing four types of dose errors in 24 Modulated Therapy Unit (MTU) plans, each planned with 6 MV Varian LINAC linear accelerator clinical head and neck IMRT plans, each planned with a step-and-shoot delivery. The error-free plans were used as a commercial treatment planning system and step-and-shoot delivery. The error-free plans were used as “simulated measurements” for generating the IMRT QA dose plans and the anatomy dose matrix) to compare to the corresponding data calculated by the error-induced plans. The degree of the induced errors was tuned to mimic IMRT QA passing rates that are commonly achieved using conventional methods.

Results: Analysis of clinical metrics (spread, mean dose, spinal cord max and D1cc, CTV D95, and target mean) vs IMRT QA Omlux analysis (P95 min, D2, P1) showed that in all cases, there were very weak to moderate correlation (range of Pearson's r -values -0.295 to 0.633). However, the moderate correlation actually had positive Pearson's r -values, indicating that some of the largest differences occurred with increasing IMRT QA passing rates, which may be called “false negatives.” The results also show superior instance of false positives or case where low IMRT QA passing rates do not imply large errors in anatomy dose matrix. In some of the cases, these correlation coefficients with high predictive power of planar IMRT passing rates, the case was false correlation consistent with high IMRT QA Omlux passing rate predicted low errors in anatomy dose matrix or vice versa.

Conclusions: There is a lack of correlation between conventional IMRT QA performance metrics (Omlux passing rate) and dose errors in anatomy regions of interest. The most common acceptance criteria and published across vendors therefore have insufficient, or at least improve, predictive power for per-beam IMRT QA. © 2011 American Association of Physicists in Medicine. DOI: 10.1118/1.3544621

Key words: IMRT QA, IMRT, quality assurance

1. INTRODUCTION

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1.A. Published studies on IMRT QA acceptance criteria

There have been many studies on suggested acceptance action levels for planar IMRT QA.²⁻⁶ Some of these studies have shown that an interceptive statistical analysis of the basic action levels on interceptive statistical analysis of the performance levels/metrics that have been achieved over many plans and IMRT beams.⁷⁻⁹ It has been suggested that passing each action level should be a requirement in order to take part in clinical trials.¹⁰ In a recent report of the AAPM Task Group 118 (Ref. 9) and, in fact, the other studies¹¹ as well, the “95% pass” criteria is common, employed as either the composite distance-to-go (DTG) metric or the

“First of all, it is intuitive that with per-patient dose errors, the importance is the location and overlap of these per-beam errors in terms of critical volumes (targets and organs at risk) [...]”¹

¹Nelms *et al.*: “Per-beam, planar IMRT QA passing rates do not predict clinically relevant patient dose errors. Med. Phys. 38 (2), February 2011”

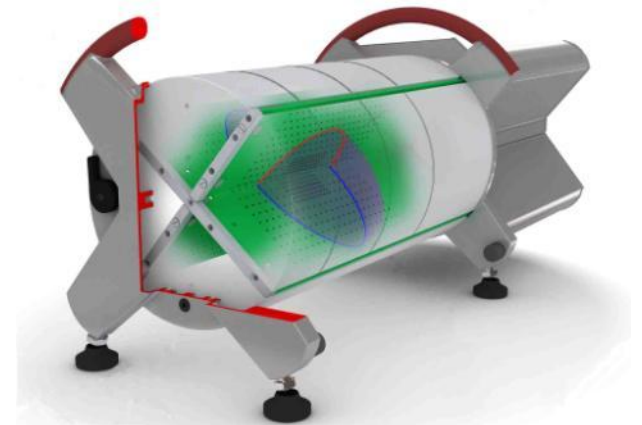
Lösung



“Gläserne Frau”, 1935, Deutsches Hygienemuseum

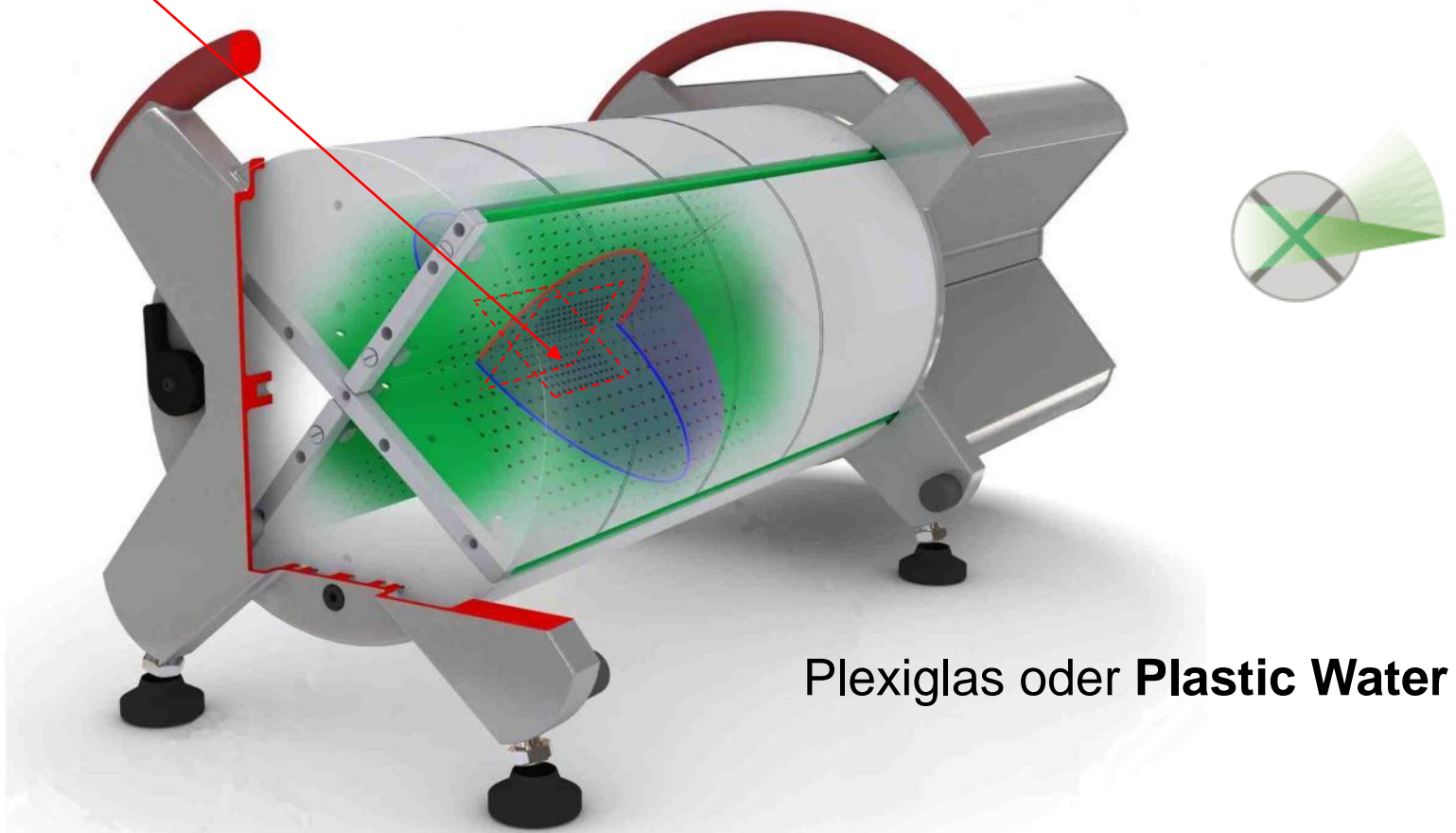
Solution: Delta4^{PT}

- Messpunkte dort, wo's drauf ankommt
- Gemessene Fraktionsdosis
- Klinische Relevanz: Überlagerung von Abweichungen mit Patientenstrukturen



Delta⁴PT

Zentralbereich 6x6cm: Ca. 300 Detektoren, Detektorabstand: 5mm
Insgesamt 1069 Detektoren
Diagonale oder horizontelle/senkrechte Orientierung



Plexiglas oder **Plastic Water**

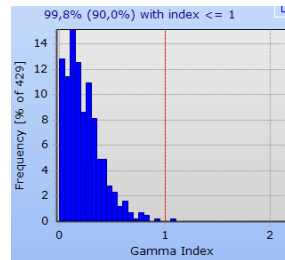
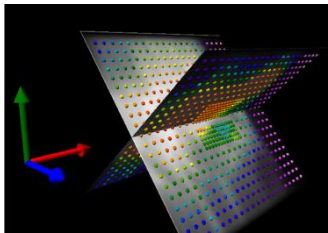
Lösung: Delta⁴PT 3D and DVH Options

Messen dort, wo's drauf ankommt

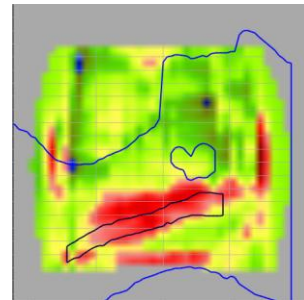
Analyse

Automatische
OK/Nicht OK Indikation

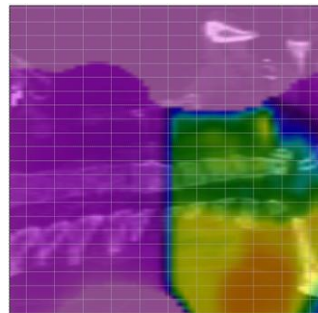
Akzeptanz



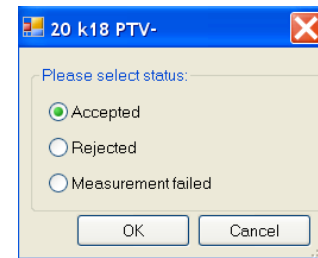
Messpunkte



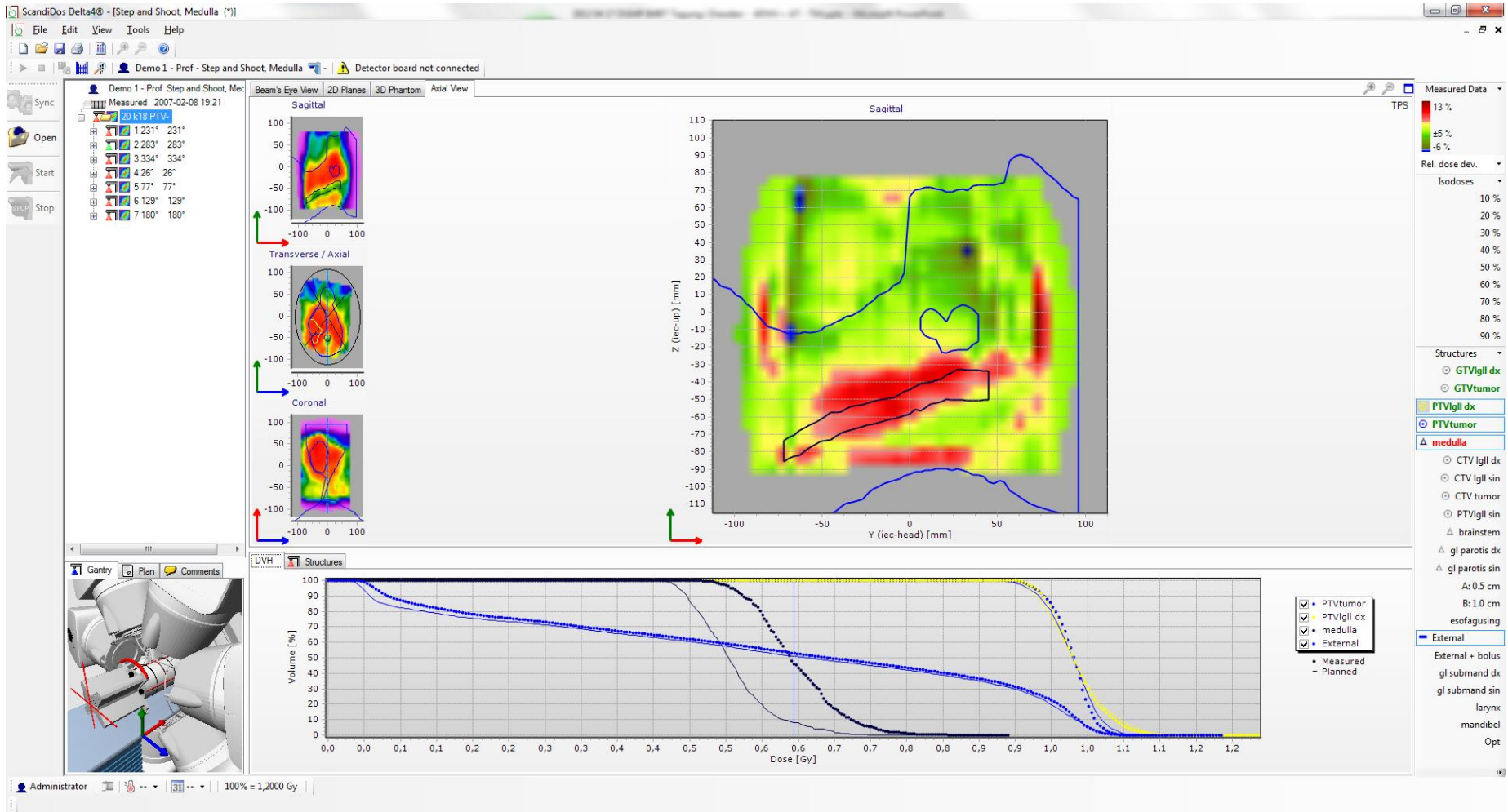
Abweichung per Struktur
in Phantom...



...oder im Patienten



DVH



D-Abw, DTA, Gamma... per Organ

The screenshot displays the ScandiDos Delta4 software interface. The main window shows a Sagittal view of a patient's anatomy with a color-coded dose distribution. Two inset images show zoomed-in views of the dose distribution. The 'Pass / Fail Criteria' dialog box is open, showing settings for Dose Deviation, Distance to Agreement (DTA), and Gamma Index. The 'Save in Acceptance Template' dialog box is also open, showing a list of templates: Breast, Head & Neck, and Prostat. The data table at the bottom provides a summary of the analysis results for various organs at risk (OARs).

Pass / Fail Criteria

Dose Deviation

Pass if 90,0 % have a deviation within - 50 % to + 1,0 %

Include detectors in dose range 20 % to 500 %

Distance to Agreement, DTA

Pass if 90,0 % have a DTA <= 3,0 mm

Include detectors where gradient is >= 1,0 % / mm

Gamma Index

Pass if 90,0 % have a gamma index <= 1.0

Max dose deviation ± 3,0 %

Max spatial deviation ± 3,0 mm

Include detectors in dose range 20 % to 500 %

Normalize deviation to local dose (Local Gamma)
(Common for all structure categories)

Save in Acceptance Template

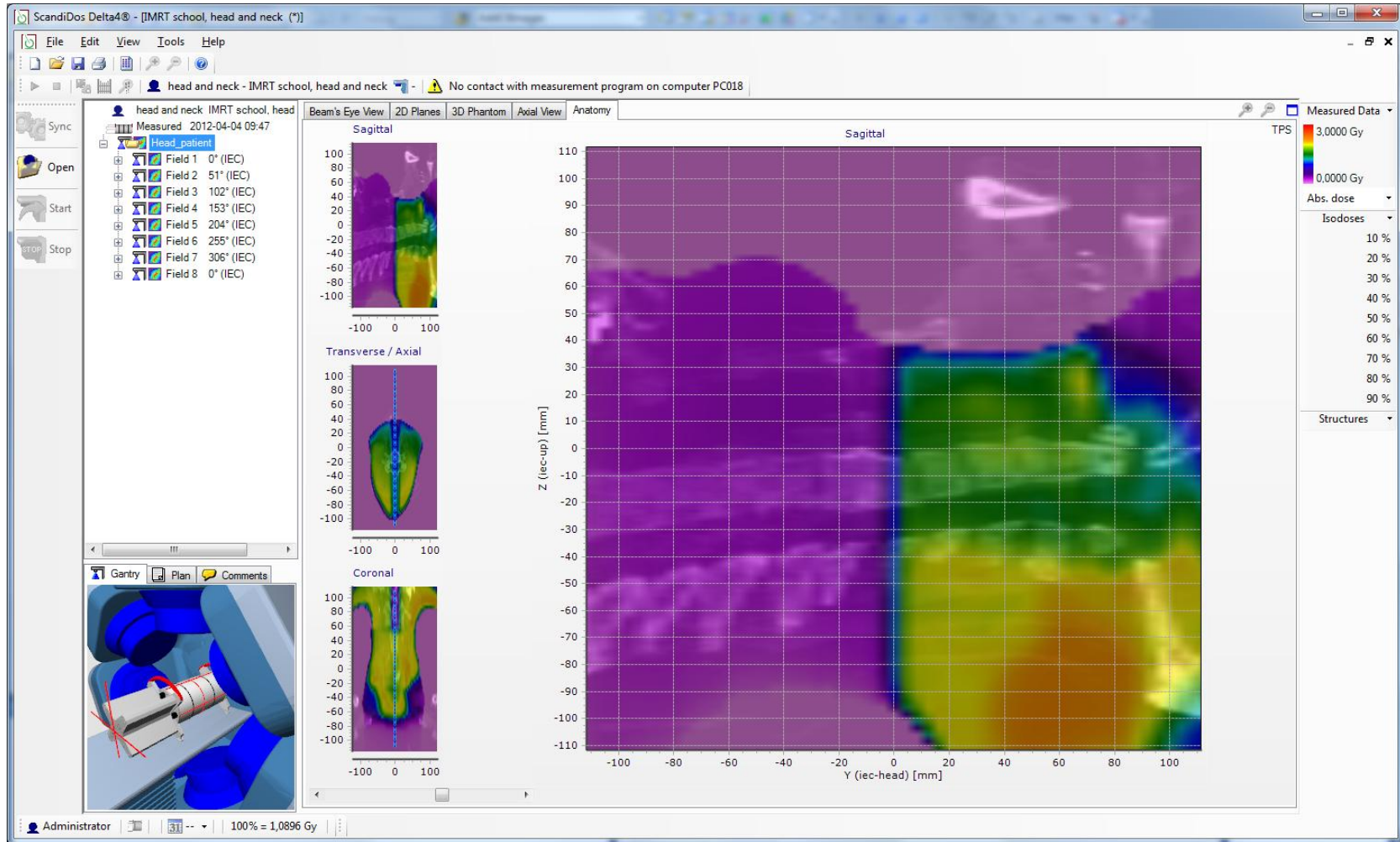
Templates

- Breast
- Head & Neck
- Prostat

Data Table

ser	Dose_mean	Dose_ref_mean	V_tot	V_used	V_ddev	V_dta	V_gamma
0 Gy	0,997 Gy	0,994 Gy	4,4 cm ³	4,4 cm ³	4,4 cm ³	0,0 cm ³	4,4 cm ³
5 Gy	1,036 Gy	1,032 Gy	75,4 cm ³	75,4 cm ³	75,4 cm ³	0,0 cm ³	75,4 cm ³
14 Gy	1,034 Gy	1,033 Gy	131,8 cm ³	131,8 cm ³	131,8 cm ³	0,9 cm ³	131,8 cm ³
11 Gy	1,028 Gy	1,028 Gy	226,3 cm ³	226,3 cm ³	226,3 cm ³	3,0 cm ³	226,3 cm ³
57 Gy	0,646 Gy	0,559 Gy	29,5 cm ³	26,5 cm ³	26,5 cm ³	9,1 cm ³	26,5 cm ³
11 Gy	0,627 Gy	0,605 Gy	6016,9 cm ³	1639,3 cm ³	1244,4 cm ³	543,3 cm ³	1244,4 cm ³

...im Patienten



ESTRO 2012

Lösung



“Gläserne Frau”, 1935, Deutsches Hygienemuseum

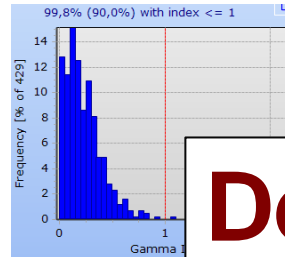
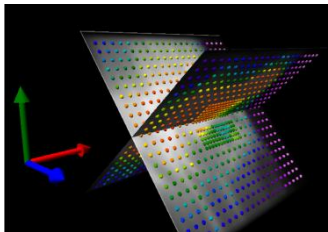
Delta⁴DVH

Messen dort, wo's drauf ankommt

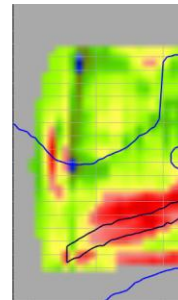
Analyse

Automatische
OK/Nicht OK Indikation

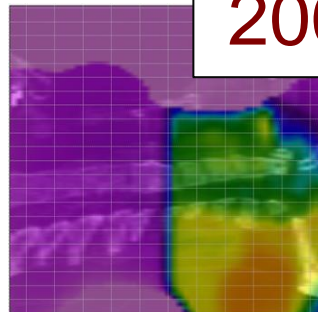
Akzeptanz



Messpu



Abweichung p
in Phant

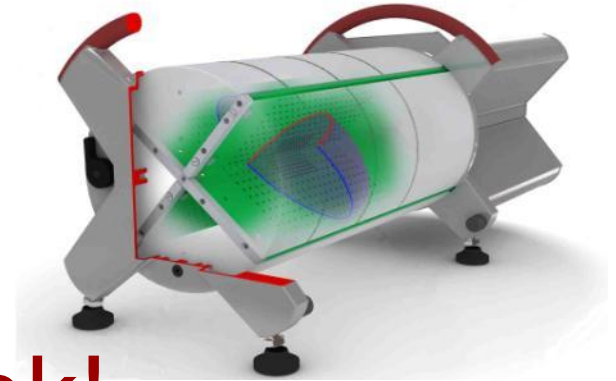
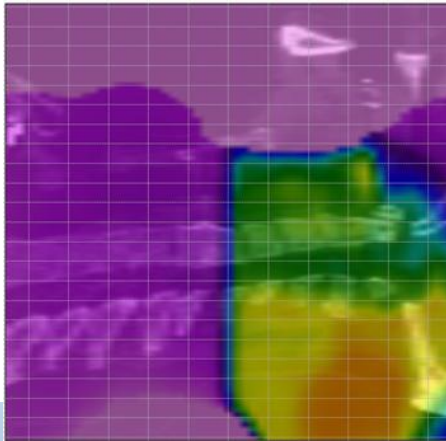


...oder im Patienten

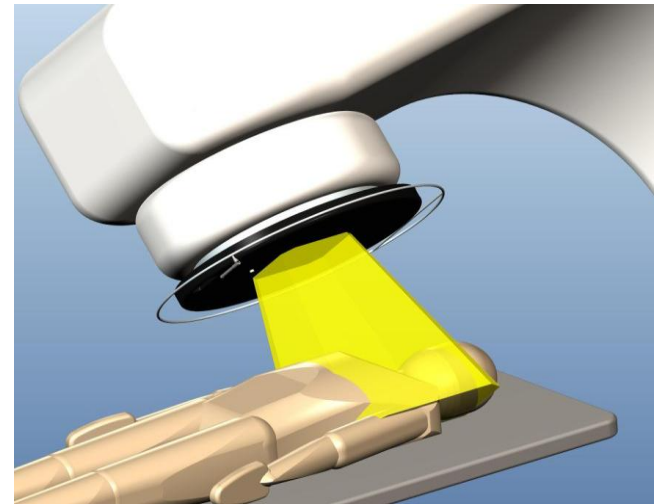
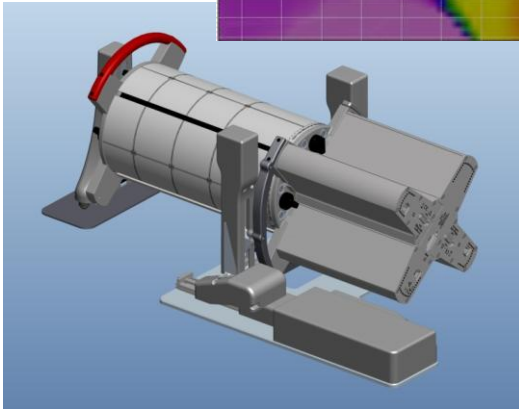
Delta⁴PT

- Misst dort, wo's drauf ankommt
- Abweichung per Organ...
 - im Phantom
 - oder im Patienten
- QS: klinische Relevanz (seit 2007!)

The Growing Delta⁴ Family



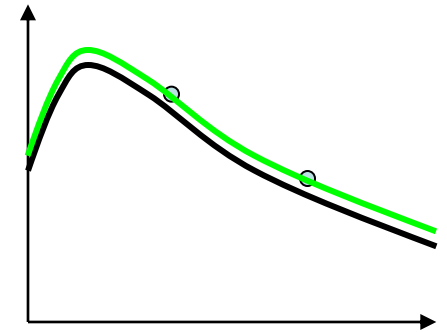
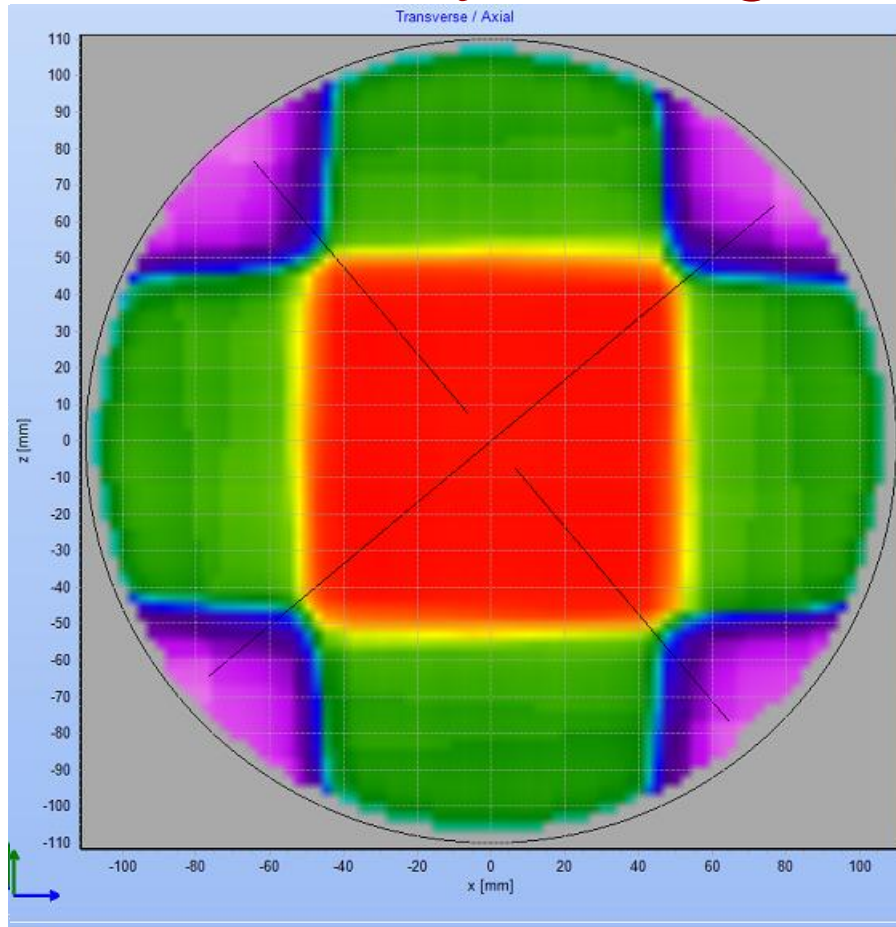
Vielen Dank!



2012-05-01

3D Dose:TPS method

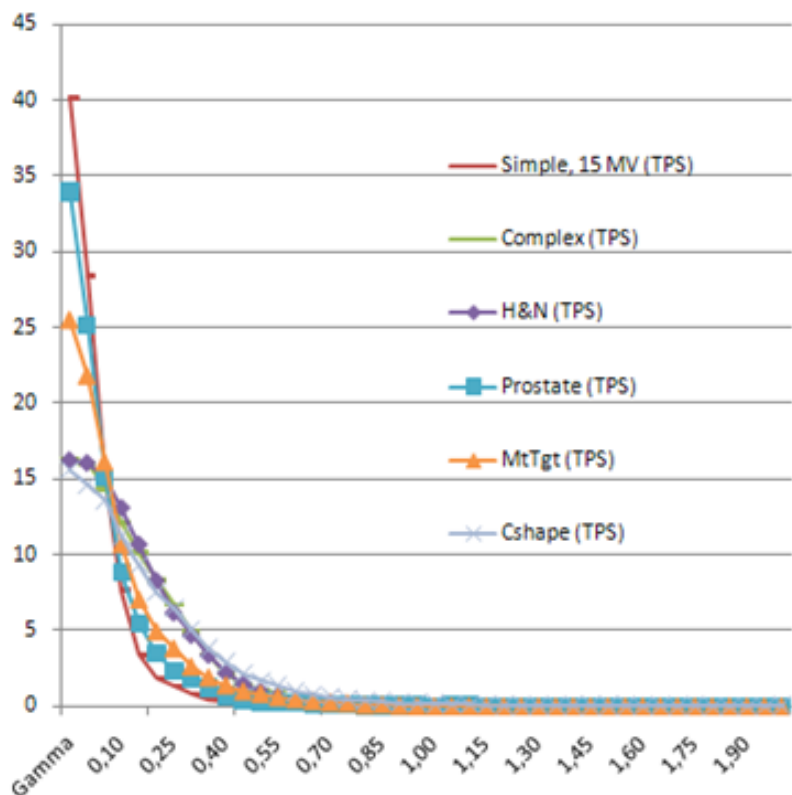
- Beam level: Ray tracing



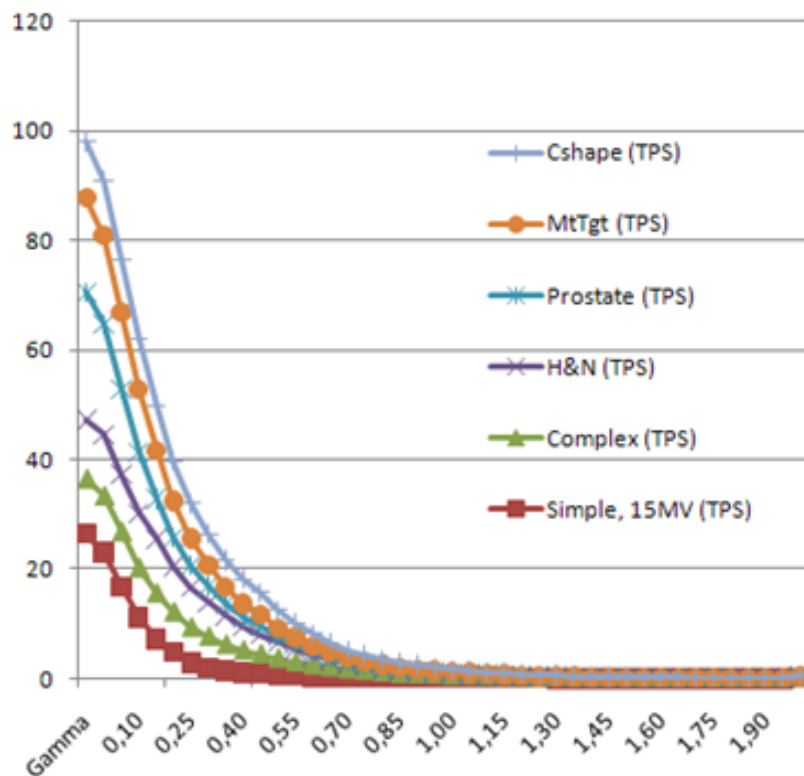
Accuracy in 3D calculation using current TPS-method in Delta⁴

Six treatments cases (ref 2) were used in the evaluation; H&N, Prostate, C-shape tumor and various energies. The pass rate for Gamma-index (3%, 3mm) was always above 99% and Gamma-index (2%, 2mm) varied from 95.3% to 99.5% when data points above 20% were included.

Gammaindex (3%, 3mm)

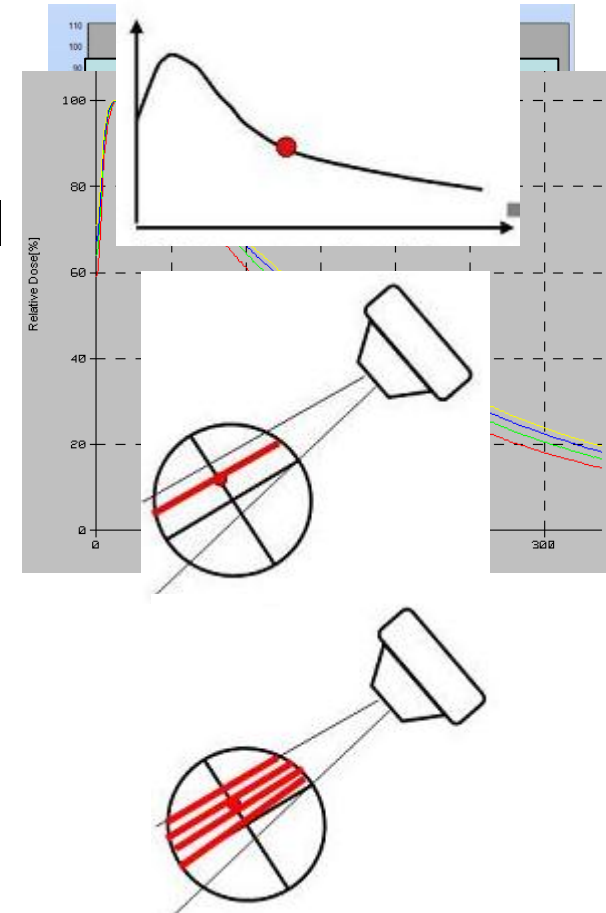


Gammaindex (2%, 2mm)



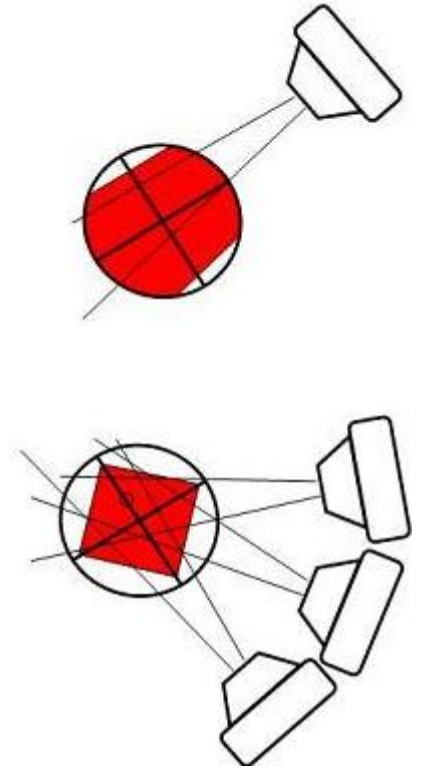
Fast-3D Dose, independent on TPS data

- Depth doses for various field sizes are calculated in Delta⁴ phantom using TPS
- The equivalent field size for each control point is calculated
- The depth dose for the equivalent field size is interpolated
- The depth dose is normalized to the measured dose
- All “depth doses” are calculated



3D Dose independent on TPS data

- Depth doses for various field sizes are calculated in Delta⁴ phantom using TPS
- The equivalent field size for each control point is calculated
- The depth dose for the equivalent field size is interpolated
- The depth dose is normalized to the measured dose
- All “depth doses” are calculated
- All control points doses are calculated

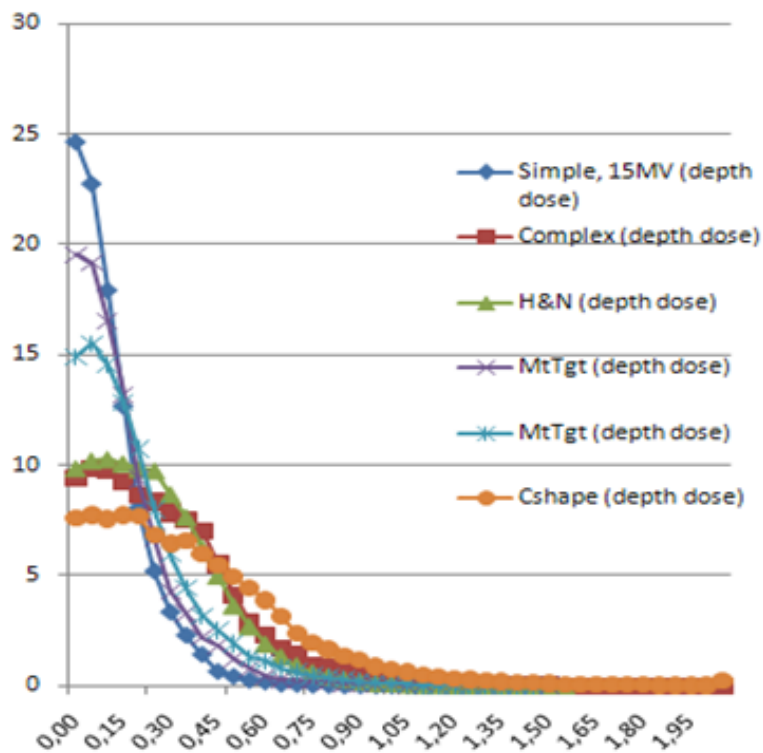


Accuracy in 3D calculation using FAST-3D calculation method in Delta⁴

The same six treatments cases as above were used in the evaluation; H&N, Prostate, C-shape tumor and various energies.

The pass rate for Gamma-index (3%, 3mm) was close or above 99% for all but the C-shape case (96%) and Gamma-index (2%,2mm) varied from 84% to 99% when data points above 20% were included.

Gammaindex (3%, 3mm)



Gammaindex (2%, 2mm)

