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# Integral Quality Monitor System

IQM Publications  
August 2019

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IRT SYSTEMS GmbH  
Schloßstraße 1 - D-56068 Koblenz  
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Publications in scientific journals:	9
Poster / Presentations at scientific conferences:	14
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Total Number of publications:	35

## Publications in scientific journals

### Sensitivity evaluation of two commercial quality assurance systems to organ-dose variations of patient-specific VMAT plans

Oluwaseyi M. Oderinde & Freek Du Plessis

University of the Free State, Bloemfontein, Republic of South Africa

The purpose of this study was to assess the dose variation sensitivity of two quality assurance (QA) devices (Integral quality monitoring (IQM®) and MatriXXEvolution systems) used for radiotherapy verification. Six volumetric-modulated arc therapy (VMAT) radiation plans were calculated, namely, three head-and-neck and three prostate cases. For sensitivity evaluation, the planning target volume (PTV) dose for each patient's plan was modified by 0.5%, 1.0%, 2.0%, and 3.0% of its original dose. The IQM and MatriXX detectors are sensitive to the dose errors considered. At 0.5% PTV dose modification, the average local percentage differences for the IQM are  $0.27 \pm 0.29$ ,  $0.24 \pm 0.35$ ,  $0.42 \pm 0.39$ ,  $0.74 \pm 0.28$ ,  $0.41 \pm 0.24$ , and  $0.26 \pm 0.32$ , while the average local percentage differences for the MatriXX device are  $1.37 \pm 0.25$ ,  $1.30 \pm 0.75$ ,  $2.82 \pm 1.46$ ,  $1.34 \pm 1.29$ ,  $1.58 \pm 0.97$ , and  $1.13 \pm 0.97$ . The sensitivity of the detectors is more pronounced in VMAT plan errors containing larger segments. This shows that the sensitivities of the detectors are plan and fraction specific. Both detectors are sensitive to dose variation in the clinical plans to a minimal dose deviation of 0.5%. The IQM detector shows the capability to be used for QA procedures and for real-time beam output monitoring.

[Click here to download the article](#)

### Sensitivity of the IQM transmission detector to errors of VMAT plans

Gary Razinkas, Sonja Wegener, Johannes Greber, Otto A. Sauer

University of Wuerzburg, Germany

This article verifies the accuracy of the signal prediction for the Synergy Agility MLC. Tolerance criteria for VMAT plan verification with the IQM were obtained from the observed sensitivity for the detection of incorrectly delivered plans. This study used 60 VMAT plans to compare the measured and the calculated signal. Small, random deviations were introduced into some plans to test the error detection capability of the IQM System. Download this article to learn that the IQM calculation algorithm correctly predicts the measured signals for VMAT plans of different plan types, such that suitable tolerance criteria could be identified. Furthermore, it was shown that purposely induced systematic and random errors could be detected with the IQM. In addition to the cumulative IQM signal, analyzing running averages over three or five segments proved a higher sensitivity for errors and therefore a combined evaluation of both criteria is the preferable method for patient-specific QA.

The IQM performance was comparable to currently used standard QA approaches using the gamma analysis. We, therefore, conclude that the IQM has the potential to be used as a routine pretreatment QA tool for VMAT QA.

[Click here to download the article](#)

### Comparison of MLC error sensitivity of various commercial devices for VMAT pre-treatment quality assurance

Masahide Saito, Naoki Sano, Yuki Shibata, Kengo Kuriyama, Takafumi Komiyama, Kan Marino Shinichi Aoki, Kazunari Ashizawa, Kazuya Yoshizawa, Hiroshi Onishi

University of Yamanashi, Japan

This article compares the MLC error sensitivity of various measurement devices for VMAT pre-treatment quality assurance (QA). This study used four QA devices (Scandidos Delta4, PTW 2D-array, iRT systems IQM, and PTW Farmer chamber). Nine retrospective VMAT plans were used and nine MLC error plans were generated for all nine original VMAT plans. Download this article to learn about the unrivaled error sensitivity of the IQM transmission detector for systematic MLC errors, especially for small aperture sizes, such as for lung SBRT.

[Click here to download the article](#)

### Error detection with real-time beam monitoring and clinical impact on radiotherapy treatment quality

Livia Marrazzo, Chiara Arilli, Marlies Pasler, Martijn Kusters, Richard Canters, Luca Fedeli, Silvia Calusi, Marta Casati, Cinzia Talamonti, Gabriele Simontacchi, Lorenzo Livi, Stefania Pallotta

This article shows the ability of detecting small delivery errors with a transmission detector for online monitoring of Intensity Modulated Radiation Therapy (IMRT) treatments. It also evaluates the correlation between the changes in the detector output induced by small delivery errors with other metrics commonly employed to quantify the deviations between calculated and actually delivered dose distributions.

[Click here to download the article](#)

### An integral quality monitoring system for real-time verification of intensity modulated radiation therapy

Mohammad K. Islam, Bernhard D. Norrlinger, Jason R. Smale, Robert K. Heaton, Duncan Galbraith, Cary Fan, David A. Jaffray

This article represents the original proof of concept for the Integral Quality Monitor System. This proof of concept convinced us to get involved with the IQM project by signing a co-development agreement with UHN Toronto and ultimately initiated the founding of iRT Systems.

Published in Medical Physics, Vol. 36, No. 12, December 2009

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### Influence of the Integral Quality Monitor transmission detector on high energy photon beams: A multi-centre study

Bozidar Casar, Marlies Pasler, Sonja Wegener, David Hoffman, Cinzia Talamonti, Jianguo Qian, Ignasi Mendez, Denis Brojan, Bruce Perrin, Martijn Kusters, Richard Canters, Stefania Pallotta, Primoz Peterlin

This article discusses the influence of the Integral Quality Monitor (IQM) transmission detector on photon beam properties. "This study demonstrates clinically negligible changes in beam quality and surface dose for all investigated beams." The authors evaluated data acquired at nine different Radiation Therapy centers and concluded that the magnitudes of changes which were found justify treating IQM either as energy-specific tray factors in the treatment planning system or alternatively as a set of modified output factors for each linac energy. This article provides valuable guidance for implementing the IQM System into the clinical routine.

Published in Zeitschrift für Medizinische Physik; Currently in press, available online March 21, 2017

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### Characterization and evaluation of an integrated quality monitoring system for online quality assurance of external beam radiation therapy

David Hoffman, Eunah Chung, Clayton Hess, Robin Stern, Stanley Benedict  
UC Davis Cancer Centre, Sacramento, USA

This article outlines a comprehensive evaluation of the Integral Quality Monitor (IQM) that took place at the UC Davis Comprehensive Cancer Center throughout the year 2015. "Our investigation has demonstrated that the IQM is stable for online delivery quality assurance measurements." The authors evaluated the IQM for a wide variety of quality assurance measurements and they concluded that the IQM System is an especially good candidate for monitoring small fields due to its unique detector design.

Published in Journal of Applied Clinical Medical Physics; Volume 18, Issue 1

January 2017

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## Sensitivity Analysis of the Integral Quality Monitoring System using Monte Carlo Simulation

Oluwaseyi Michael Oderinde, FCP du Plessis\*

Department of Medical Physics, University of the Free State, PO Box 339, Bloemfontein 9300, South Africa

Oluwaseyi M. Oderinde and his colleagues at the University of the Free State in Bloemfontein, South Africa evaluated the sensitivity of the IQM System to errors in beam segments using EGSnrc/BEAMnrc Monte Carlo (MC) codes. The authors show the potential of the IQM System to detect small segment alterations. This article was published in "Computational and Mathematical Methods in Medicine", Vol. 2017 and shows the error sensitivity of the IQM System during online beam monitoring.

[Click here to download the presentation](#)

## A new wedge-shaped ionization chamber component module for BEAMnrc to model the IQM system

Oluwaseyi M. Oderinde and F. C. P. du Plessis

Department of Medical Physics, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa

Oluwaseyi Michael Oderinde and his colleagues at the University of the Free State in Bloemfontein, South Africa developed a new component module (CM) to accurately model the integral quality monitoring (IQM) system to be used in the BEAMnrc Monte Carlo (MC) code. Download this publication in "Radiation Physics and Chemistry", which serves as a basis for researchers that have an interest in MC study of wedge-shaped ionization chamber systems.

[Click here to download the presentation](#)

## Poster / Presentations at scientific conferences

### Comparison of pre-treatment Plan QA with IQM and Portal Dosimetry

M. Ghafarian, M. Morales-Paliza and M. Price

Vanderbilt University Medical Center, Nashville, Tennessee

This study by M. Ghafarian, M. Morales-Paliza and M. Price was presented as a poster at the 2019 AAPM Annual Meeting in San Antonio, TX. The clinical physics group introduced a variety of clinically significant treatment delivery errors into a variety of complex retrospective VMAT plans and compared the error sensitivity of IQM to their Portal Dosimetry system. The authors concluded that the IQM system is more sensitive to small dose differences and provides more information regarding machine output than EPID gamma analysis. Download the poster to learn how the IQM system provides a highly effective method for MLC error detection in highly complex VMAT plans..

[Click here to download the poster](#)

### Photon Beam Quality Assurance with the IQM System: A Multicenter Study

Veres, A., Farrokhkish, M., DeMarco, J., Fong de los Santos, L., Heaton, R., Islam, M.,

Mayo Clinic, Rochester, Princess Margaret Cancer Centre, Toronto, Cedars Sinai Medical Center, Los Angeles

This multi-center study was presented as a poster at the 2018 AAPM Annual Meeting in Nashville, TN. The clinical research group developed and validated an efficient machine performance and quality assurance (QA) protocol using the IQM system. The authors concluded that the IQM system provides a very efficient process for performing quality control and quality assurance of a linear accelerator. Download the poster to learn how the IQM system provides an automated approach for an efficient dosimetric characterization of a linear accelerator.

[Click here to download the poster](#)

### Real-time verification of VMAT delivery by an automated beam monitoring system

M Farrokhkish, M Islam, R Heaton , B Norrlinger , D Jaffray, Princess Margaret Cancer Centre, University Health Network, Toronto, ON

Makan Farrokhkish and his colleagues at the Princess Margaret Cancer Centre evaluated the beam monitoring performance of the IQM System to assess the accuracy and reproducibility of the linac beam delivery. The signal calculation accuracy and measurement reproducibility as well as the error detection capability of the IQM System was evaluated. For this study the author analyzed 52800 beam segments. Download the poster that was presented at the AAPM 2017 conference in Denver.

[Click here to download the presentation](#)

### Online dosimetry with the Integral Quality Monitor

Kilian Michel

Lake Constance Radiation Oncology Clinic, Friedrichshafen, Germany

Kilian Michel and his colleagues at the Lake Constance Radiation Oncology Center in Friedrichshafen, Germany have evaluated the IQM System for Online Dosimetry during the patient treatment. The long-term signal stability, the error detection sensitivity for induced errors, the correlation of the IQM and the Dose-Volume-Histogram as well as treatment plan verification with the IQM System has been evaluated.

Presentation at DEGRO, Berlin

[Click here to download the presentation](#)

## Signal Prediction for an On-line Delivery Verification System

R. Heaton, , M. Farrokhkish, G. Wilson, B. Norrlinger, D.A. Jaffray, M.K. Islam  
Princess Margaret Cancer Centre, Toronto, Canada

Robert Heaton and his colleagues at the Princess Margaret Cancer Centre in Toronto developed a calculation method to the predict the measured IQM signal for clinical IMRT fields

Poster at ESTRO 36, Vienna

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## Beam Delivery Check and In-Vivo Dosimetry during Breast Radiotherapy Treatment

Talamonti C., Marrazzo L., Arilli C., Galeotti C., Casati M., Calusi S., Domizi C., Fidanzio A., Meattini I., Scoccianti S., Bonomo P., Piermattei A., Pallotta S.

University of Florence, Department of Clinical and Experimental Biomedical Sciences "Mario Serio", Florence, Italy, Medical Physics Unit AOU Careggi, Florence, Italy, Radiotherapy Unit AOU Careggi, Florence, Italy, Università Cattolica del Sacro Cuore, Rome, Italy

Cinzia Talamonti and her colleagues from the University of Florence, Italy verified the delivery of the prescribed dose during radiotherapy treatment using the IQM in combination with portal imaging together with the software SoftDiso (Best Medical Italy Srl) for in-vivo measurements. They evaluated the ability of detecting positional and delivery errors intentionally introduced during breast treatments.

Poster at AIFM Conference in Perugia, Italy

[Click here to download the poster](#)

## Evaluation of an Integral Quality Monitor device for monitoring real-time delivery

Gloria Miori, Andrea Martignano, Loris Menegotti, Aldo Valentini

Post-graduate School of Medical Physics, University of Rome Tor Vergata, Roma, Italy, Medical Physics Department, Azienda Provinciale per i Servizi Sanitari, Trento, Italy

Gloria Miori, Andrea Martignano and their colleagues from Azienda Provinciale per i Servizi Sanitari in Trento, Italy analyzed the use of the IQM System for real-time beam delivery control. They evaluated the IQM beam attenuation and IQM's ability to detect VMAT delivery errors. They concluded that the IQM beam attenuation can be considered to be homogenous in both X and Y directions and the machine-specific beam attenuation percentage could be used to rescale treatment plan dose for clinically IQM use. IQM shows appreciable features in detecting real-time errors and for time-saving QAs.

Poster at AIFM Conference in Perugia, Italy

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## Reproducibility and sensitivity of IQM: A real-time monitoring device for complex radiotherapy treatments

Chiara Arilli, Cinzia Talamonti, Livia Marrazzo, Marta Casati, Antonella Compagnucci, Silvia Calusi, Luca Fedeli, Lorenzo Livi, Stefania Pallotta

Medical Physics Unit AOU Careggi, Florence, Italy; University of Florence, Department of Clinical and Experimental Biomedical Sciences "Mario Serio", Florence, Italy; Radiotherapy Unit AOU Careggi Florence, Italy

Chiara Arilli, Cinzia Talamonti, Livia Marrazzo and their colleagues from the AOU Careggi, Florence, Italy evaluated the output signal reproducibility and sensitivity in detecting small errors in delivery parameters of IMRT step and shoot treatments using the IQM System as well as the correlation between IQM signal variations and 3Dy, 2Dy and DVH parameters.

Poster at AIFM Conference in Perugia, Italy

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## In-Vivo Dosimetry of Stereotactic Radiation Therapy using the IQM System

Jianguo Qian, Lan Lin, Raul Gonzales, Jordie Keck, Elwood Armour, John Wong  
Department of Radiation Oncology & Molecular Radiation Sciences, Johns Hopkins University,  
USA

Jianguo Qian from the Johns Hopkins University, Baltimore draws the preliminary conclusion that IQM is a stable dosimetric system and can detect dosimetric deviations caused by small leaf errors in stereotactic radiation therapy. The sensitivity to leaf errors is more pronounced for relatively small fields (i.e., small targets) in SBRT. IQM appears to be more sensitive than Mapcheck2 to small leaf errors in SBRT of small targets while showing similar sensitivity in SBRT of relatively large targets.

Poster at ASTRO 57, San Antonio

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## Monte Carlo Study of an Integral Quality Monitoring (IQM) System

Oluwaseyi M. Oderinde, Dr. Freek C P du Plessis  
Faculty of Health Science, Department of Medical Physics, University of the Free State,  
Bloemfontein, South Africa

Oluwaseyi Oderinde from the University of the Free State, South Africa developed modelled the IQM using the BEAMnrc component module. this model stands as a basis for Monte Carlo study of the IQM system.

Poster at the SAAPMB conference in Bloemfontein, South Africa

[Click here to download the poster](#)

## Testing IQM: A system for real-time monitoring of complex radiotherapy treatments

Talamonti C., Marrazzo, L., Calusi, S., Arilli C., Casati M., Compagnucci A., Bonomo P., Livi L., Pallotta, S

University of Florence-Department of Experimental and Clinical Biomedical Sciences "Mario Serio", Florence, Italy; AOU Careggi- Physic Unit Florence, Italy; Florence, Italy; AOU Careggi-Radiotherapy Unit Florence, Italy.

Stefania Pallotta from University of Florence, Italy evaluated the IQM during the pre-clinical testing. She concludes that IQM provides optimal performance for signal reproducibility of complex IMRT plans. IQM is capable of detecting small errors in MU and leaf positions sufficient for clinical practice

Poster at the IEEE conference in Milano, Italy

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## In Vivo Dosimetry of Conventional and Rotational Intensity Modulated Radiotherapy Using Integral Quality Monitor (IQM)

Lan Lin, Jianguo Qian, Raul Gonzales, Jordie Keck, Elwood Armour, John Wong  
Department of Radiation Oncology & Molecular Radiation Sciences, Johns Hopkins University,  
USA

Mrs. Lan Lin, Medical Physicist at Johns Hopkins University evaluated the accuracy, sensitivity and constancy of the IQM for conventional intensity modulated radiation therapy (IMRT) and rotational volumetric modulated arc therapy (VMAT).

Poster at AAPM 57, Anaheim, CA

[Click here to download the poster](#)

## Initial Evaluation of the Integral Quality Monitor (IQM)

Perrin B, Garner A., Beck JA, Speakman R., Budgell G.

CMPE, Christie Hospital NHS Trust, Withington, Manchester, M20 4BX

Mr. Bruce Perrin, Medical Physicist from The Christie Hospital in Manchester validated the effectiveness and reliability of the IQM to monitor the correct delivery of daily fractions.

Presented at UKRO Conference in Birmingham, UK

[Click here to download the presentation](#)

## Response Characteristics of a Large-Area Ion Chamber with Various Radiotherapy Beams

Makan Farrokhkish

Department of Radiation Physics, Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto

Presentation about the response characteristics of the IQM system with different beams.

Presented at the World Congress on Medical Physics & Biomedical Engineering 2015 in Toronto

[Click here to download the presentation](#)

## User presentations at iRT events (without peer review)

### IMRT Plan QA with the IQM detector

Sonja Wegener, Barbara Herzog, Otto A. Sauer

University Clinic Wuerzburg, Germany

Sonja Wegener and her colleagues from the University of Wuerzburg, Germany evaluated the IQM System for IMRT plan QA. The IQM Calculation algorithm has been validated for a wide spectrum of clinical IMRT cases. The error sensitivity of the IQM System has been tested with a variety of induced errors. The error detection capability of the IQM System has been compared against their current IMRT QA approaches.

Presented at ESTRO 36, Vienna

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### The physics behind the IQM Signal

Robert Heaton

Princess Margaret Cancer Centre, Toronto, Canada

Robert Heaton from the Princess Margaret Cancer Centre in Toronto, Canada presented the calculation model of the IQM System in terms of the physical characteristics and behavior of linear accelerators.

Poster / Presentation at ESTRO 36, Vienna

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### Delivery errors detectability with IQM

Livia Marrazzo, Chiara Arilli, Marta Casa, Silvia Calusi, Cinzia Talamonti, Luca Fedeli, Gabriele Simontacchi, Lorenzo Livi, Stefania Pallota

Medical Physics Unit AOU Careggi, Florence, Italy, University of Florence, Department of Clinical and Experimental Biomedical Sciences "Mario Serio", Florence, Italy, Radiotherapy Unit, AOU Careggi, Florence, Italy

Livia Marrazzo and her colleagues at the AOU Careggi in Florence evaluated the correlation between the changes in the detector output signal induced by small delivery errors with other metrics, such as the  $\gamma$  passing rate and the DVH variations. They concluded that IQM is capable of detecting small delivery errors and that it exhibits a good correlation with other metrics currently used to determine the quality of a treatment plan.

Presented at ESTRO 35, Torino

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### Verifying Total Body Irradiation using the IQM System

G. Guidi, N. Maffei, P. Ceroni, G.M. Mistretta, A. Bernabei, L. Morini, T. Costi

Medical Physics Department Az. Ospedaliero Universitaria di Modena, Physics Department, Alma Mater Studiorum University of Bologna, Radiation Oncology Department. Az.

Ospedaliero Universitaria di Modena

Gabriele Guidi and his colleagues from Az. Ospedaliero Universitaria di Modena evaluated the use of IQM for the verification of TBI treatments. They investigated the influence of the IQM Detector on depth dose curves and beam profiles for an extended SSD of 170cm. The presentation outlines the considerations that should be applied when utilizing IQM for TBI verification. They concluded that IQM can be used for TBI verification

Presented at ESTRO 35, Torino

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## Integrating the IQM into a commercial planning system

Perrin B, Freer L, Beck JA, Speakman R, Budgell GJ

CMPE, Christie Hospital NHS Trust, Withington, Manchester, M20 4BX

Bruce Perrin and his colleagues at the Christie Hospital investigated potential challenges when integrating IQM into a commercial planning system. They compared data measured in a waterphantom with and without the IQM detector for various energies (6,10 & 6FFF). They evaluated the IQM data against clinical models in Pinnacle 9.8 and analyzed the magnitude of adjustments assessed. They finally verified their results by delivering various treatment plans to the Delta 4 through IQM.

Presented at ESTRO 35, Torino

[Click here to download the presentation](#)

## Pre-clinical tests of the IQM System

Marlies Pasler

Lake Constance Radiation Oncology Center Friedrichshafen

Marlies Pasler and her colleagues at the Lake Constance Radiation Oncology Center in Friedrichshafen, Germany investigated the potential of the IQM System to catch errors before they become clinically relevant. They also checked if IQM would help them to improve the efficiency of their processes and finally they checked if IQM would replace their current pre-treatment QA. They concluded that IQM could improve the efficiency of their workflow and that the error detection capabilities are sufficient for clinical practice.

Presented at ESTRO 35, Torino

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## Performance Study of an automated real-time monitoring system for SBRT treatments

Makan Farrokhkish

Department of Radiation Physics, Radiation Medicine Program

Princess Margaret Cancer Centre, Toronto

Makan Farrokhkish from the Princess Margaret Cancer Centre, Toronto states that IQM is well suitable to verify state-of-the-art SBRT treatments utilizing FFF Rapid Arc treatments on a Varian TrueBeam linear accelerator

Presented at ASTRO 57, San Antonio

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## Real-time detection of deviations in radiotherapy beam delivery using a head-mounted detector

Martijn Kusters PhD, Richard Canters PhD,

Radboud UMC, Nijmegen, The Netherlands

Martijn Kusters from Radboud UMC, Nijmegen, The Netherlands states that IQM enables a clinic to do real-time, intra-fraction monitoring of beam delivery. The error sensitivity and specificity can be expected to be sufficient for clinical practice, and performs at least as well as their current equipment (Scandidos Delta 4)

Presented at ASTRO 57, San Antonio

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## Efficient and Enhanced QA Testing of Linear Accelerators using a Real-time Beam Monitor

Andrew Jongho Jung

Princess Margaret Cancer Centre, Toronto, Canada

Mr. Andrew Jung evaluated the possibility to utilize the IQM system for a variety of Linac QA purposes.

Download the full presentation that was held at the iRT booth during the AAPM 2015 meeting in

Presented at AAPM 57, Anaheim, CA

[Click here to download the presentation](#)

## Online quality assurance of external beam radiation therapy with an integrated quality monitoring system

David Hoffman, Ph.D.

University of California, Davis

Dr. David Hoffman at UC Davis evaluated the stability and accuracy of each feature of the IQM.

Presented at AAPM 57, Anaheim, CA

[Click here to download the presentation](#)

## Quality Assurance with the IQM system - the Radboud UMC experience

Richard Canters, Martijn Kusters

Radboud UMC, Nijmegen, The Netherlands

Richard Canters from Radboud UMC, Nijmegen, The Netherlands participated in the pre-clinical evaluation of the IQM system. He found out that IQM detects small errors in beam delivery with respect to pre-calculated beams, it detects small errors during a treatment course with respect to reference beams, IQM operates with almost no user interaction necessary and that it closes the TPS – R&V – Linac circle.

Presented at the 3rd ESTRO Forum, Barcelona

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## Preliminary tests with the IQM system - the University of Florence experience

Dr. Stefania Pallotta

Careggi University - Hospital Florence

Dr. Stefania Pallotta states that IQM provides an optimal performance for IMRT QA. Intra-fractional %STD of 0.04% and inter-fractional %STD of up to 0.36% for complex IMRT cases over a period of multiple weeks are the results of this study.

Presented at the 3rd ESTRO Forum, Barcelona

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