Technical infrastructure for large-scale 2D portal dosimetry

S.M.J.J.G. Nijsten, L.C.G.G. Persoon, W.J.C. van Elmpt, F. Verhaegen

Department of Radiation Oncology (MAASTRO), GROW, University Medical Center Maastricht, Maastricht, The Netherlands

Abstract

Electronic Portal Imaging Devices (EPIDs) are usually applied for patient set-up verification and detection of organ motion in clinical routine. A rather new application is the usage of EPIDs for dosimetric verification of a treatment. In literature, several papers can be found describing different methods to use an EPID for verification of the dose in the EPID plane behind a patient (2D transit dosimetry) and even inside a patient (3D in-vivo dosimetry). However, few departments really use their dosimetric EPID methods in clinical routine for large-scale patient treatment verification.

In our department, 2D portal dosimetry is applied to all patients treated with a curative intent. Due to the vast amounts of images resulting from these procedures, a technical infrastructure is designed and implemented to handle all portal dose information, allowing for a workflow with minimum user intervention. Clinical reliability is estimated to be 99%.

Keywords

Portal dosimetry, workflow automation, DICOM services, PACS

Introduction

In our department, verification procedures based on 2D portal dosimetry are heavily investigated and clinically implemented in recent years [1]. Based on portal image measurements using EPIDs, dose conversions are performed to obtain 2D absolute portal dose images in water measured under full scatter conditions. These measured portal dose images (PDIs) are compared to reference portal dose images obtained from 2D pre-treatment and transit portal dose predictions [2], using the gamma evaluation method [3]. Based on individual gamma images and trends in gamma parameters, beam delivery errors and patient related delivery errors like set-up errors and organ motion can be detected, which can result in treatment adaptation by repeated CT scanning and repeated treatment planning.

To allow the large-scale application of 2D portal dosimetry in clinical practice, a technical infrastructure is developed which automates all portal dosimetry calculations and minimizes user interventions during the entire workflow. This work shows the overall infrastructure, the clinical implementation and workflow of 2D portal dosimetry, including some statistics for the image handling process and its clinical reliability.

Material and methods

Technical infrastructure

In our department, a technical infrastructure is used to process and store different types of information (Figure 1). This information can originate from 2D, 3D or 4D imaging, treatment planning, *image-guided* and *dose-guided* radiation therapy. Most information is generated by our department, but information may also originate from an external, referring hospital (e.g. computed tomography or magnetic resonance imaging scans).

All information is collected and stored in a central Picture Archiving and Communication System (PACS) [4-6] which means that all information should be present in or converted to a standard format, which is in our case the DICOM (Digital Imaging and Communications in Medicine) format [7-8]. To get all DICOM objects of a patient grouped together in the central PACS database, naming conventions and patient IDs should be normalized. Therefore, a connection is set-up with our Electronic Medical Record (EMR) which is the leading source of personal medical information of a patient. All DICOM objects that enter the central PACS database are forced to conform to the EMR by using an in-house developed software package called DIGITrans. Besides ensuring consistency between EMR and PACS, this software also validates every DICOM object, e.g.: is it allowed to store a

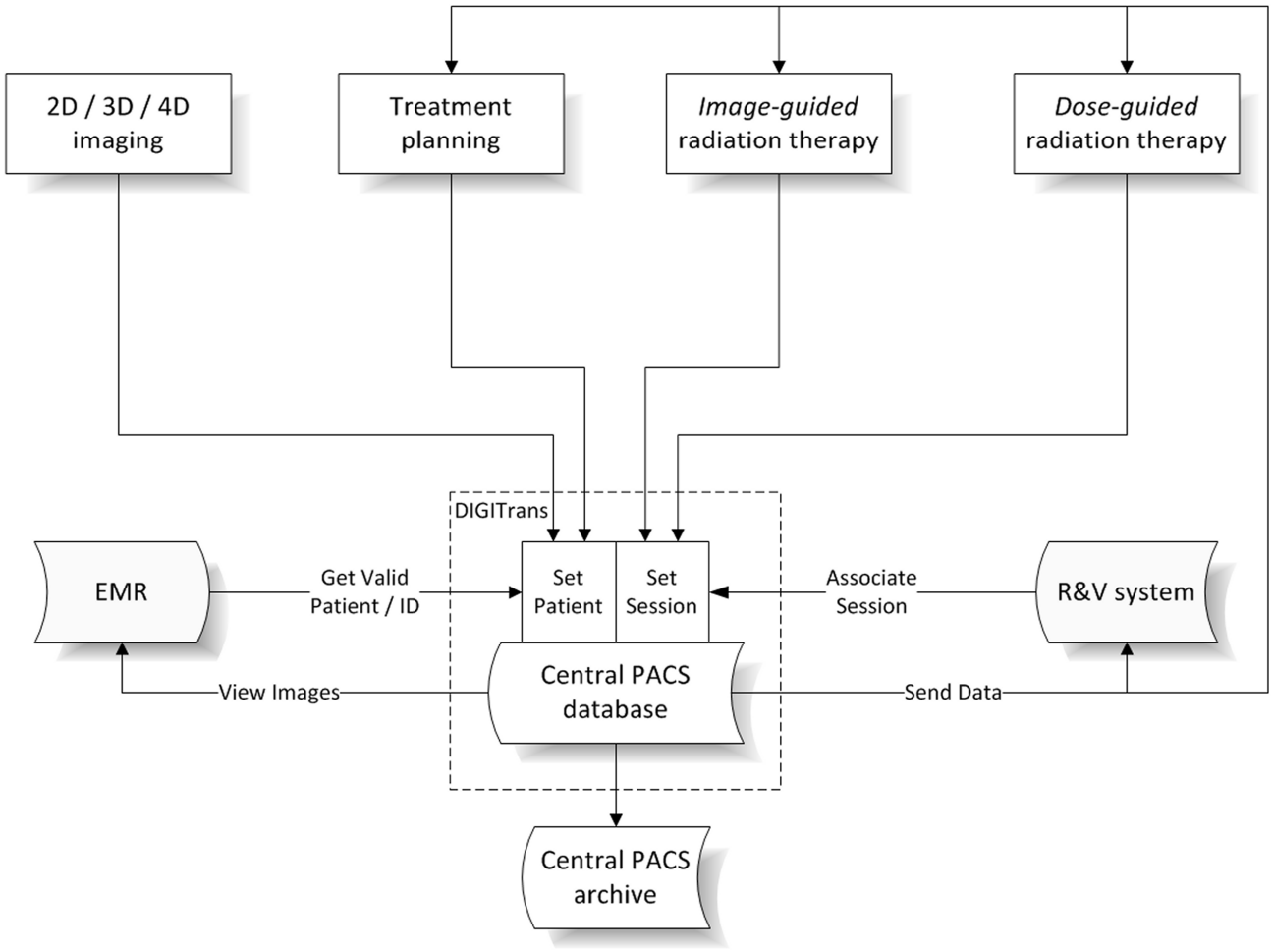


Figure 1: Overview of the technical infrastructure for handling and storing information.

DICOM object in the central PACS database or are the treatment parameter values such, that the treatment plan can be delivered with the treatment equipment?

DIGITrans is a stand-alone application with multiple event-based interconnected DICOM services. For instance, one DICOM service associates DICOM objects acquired during treatment verification with a specific treatment session. In this case, fractionation information is retrieved from the record-and-verify (R&V) system. After patient treatment, data in the central PACS can be archived by moving it to another PACS which serves as the central archive of our department.

DICOM services for 2D portal dosimetry

The most important building blocks of two-dimensional portal dosimetry are a number of DICOM services which interact on the central PACS database. These DICOM services are schematically shown in Figure 2 and are initiated after receiving a DICOM object 1) manually by user intervention or 2) automatically by another DICOM service. The services retrieve additional DICOM information from the central PACS database and also store newly calculated DICOM objects in this database. Another output type is web reporting where HTML pages are stored on a network share.

The structure projection starts when the corresponding DICOM service retrieves a 3D structure set from DIGITrans (RTSTRUCT 3D) and calculates 2D contours (RTSTRUCT 2D) in the EPID plane per beam. The calculation also uses the treatment plan (RTPLAN), which is automatically extracted from the central PACS.

The pre-treatment dose prediction calculates an open field portal dose image (RTDOSE PRED P) per beam. In this case, the input DICOM object is the treatment plan.

The transit dose prediction is triggered automatically by the pre-treatment dose prediction after the open field PDI is calculated. Secondary input DICOM objects of the DICOM service that predicts a transit PDI (RTDOSE PRED T) are the treatment plan and the planning CT scan of a patient (CT).

Both portal dose predictions can be done within 10-15 minutes per IMRT treatment plan depending on the number of segments per beam. For non-IMRT treatment plans, the calculation time per beam is about 5-7 s and 60-70 s for the pre-treatment and transit dose prediction, respectively.

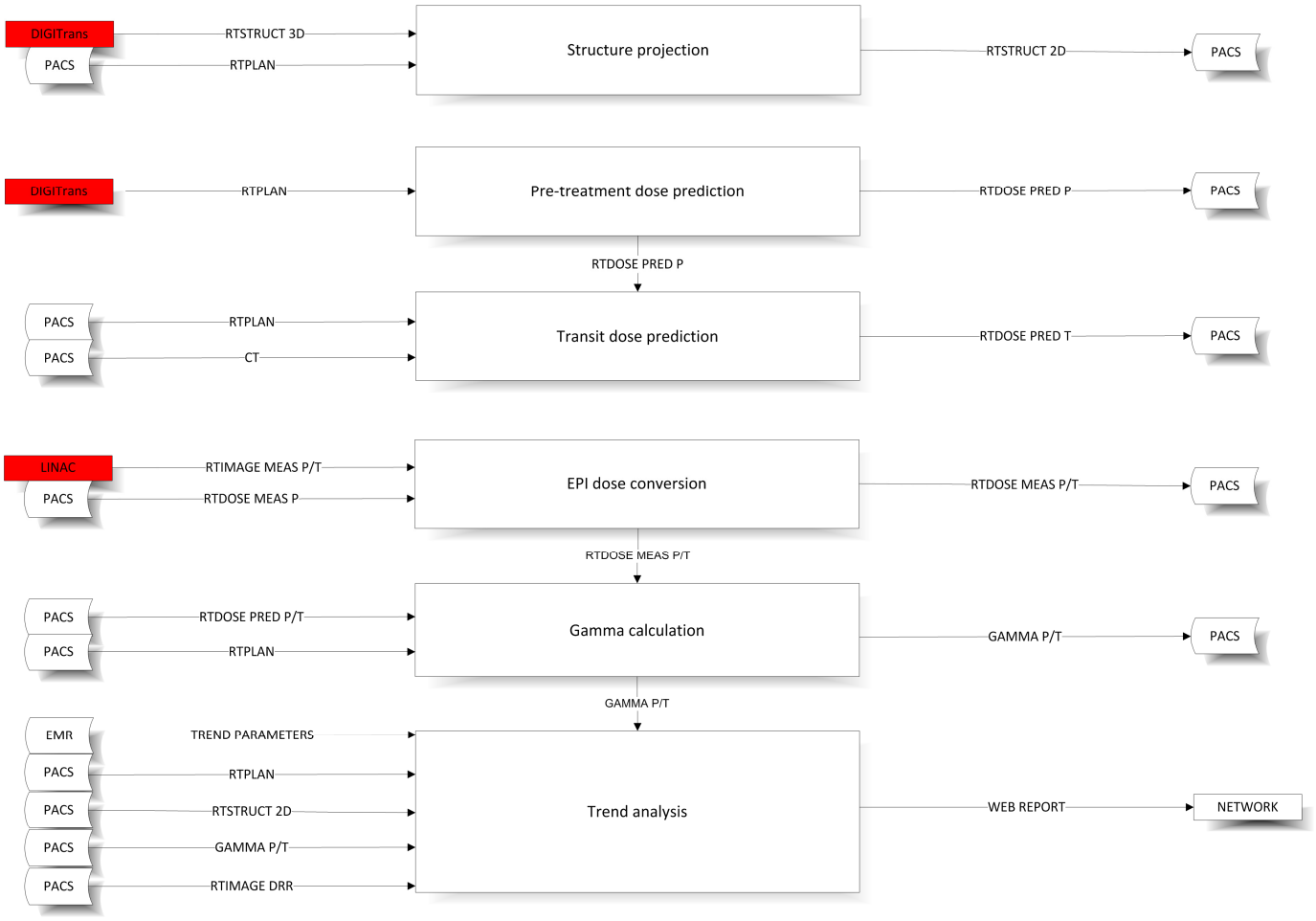


Figure 2: Overview of the DICOM services which are the most important elements of the 2D portal dosimetry workflow. All calculated DICOM objects (e.g. portal dose images and gamma images) are stored in the central PACS database shown in Figure 1 while web reports are stored on a network share. User interventions are shown in red.

The EPI dose conversion is started after the acquisition of the first portal image has been performed and the image (RTIMAGE MEAS P/T) is auto-forwarded by the linear accelerator console to this DICOM service. This means that the first dose conversions (RTDOSE MEAS P/T) are already finished during the course of a treatment session. In case of transit dosimetry, transmission values are calculated based on measured pre-treatment EPID images. The DICOM service therefore uses open field portal dose images as secondary input. EPI dose conversions are done within 10-20 s per portal image.

The gamma calculation is automatically triggered by the EPI dose conversion. Besides a measured portal dose image, the corresponding predicted portal dose image and the treatment plan are retrieved from the central PACS database as secondary input. The treatment plan is used to calculate a treatment field mask which is applied during the automatic gamma image analysis. Finally, the gamma image and the results of the gamma analysis are stored in the central PACS in DICOM RTDOSE format. The maximum calculation time of a gamma image is 15-20 s.

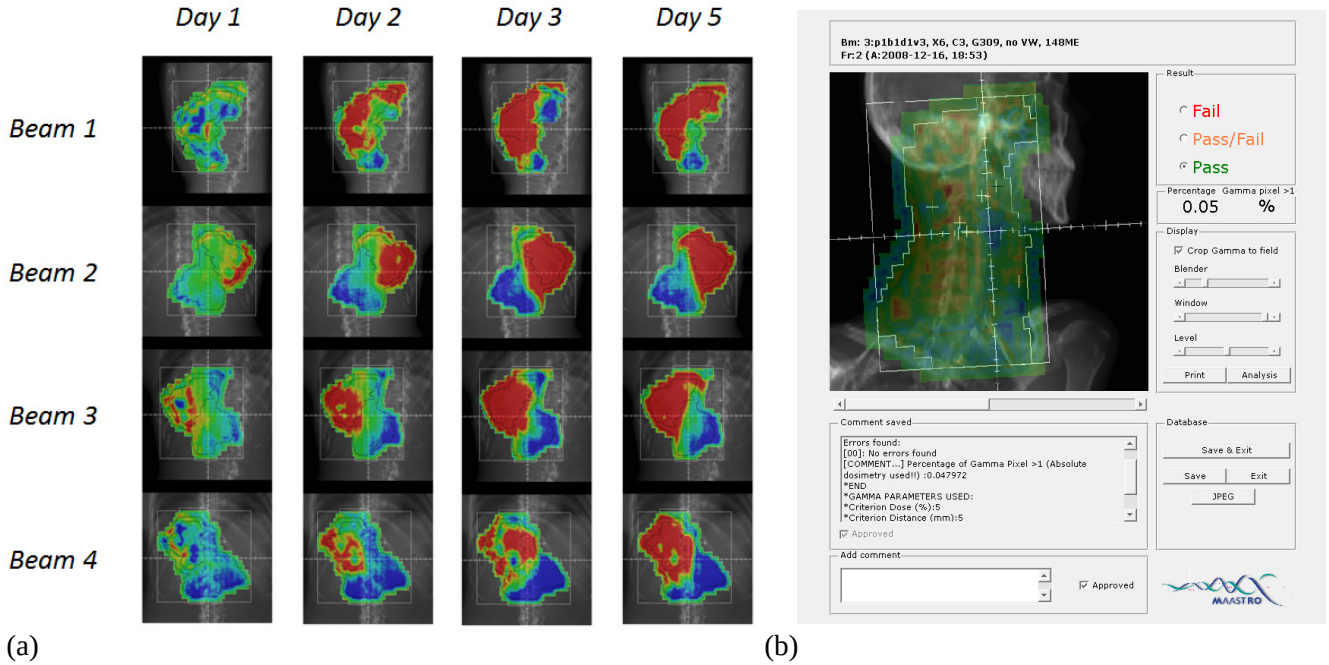
The last DICOM service analyzes all gamma images for a patient treatment and determines if treatment adaptation is needed based on trend analysis and decision protocols. These decision protocols are defined per treatment protocol from the EMR and prescribe which gamma parameters, 2D contours and tolerance levels should be used. The trend analysis DICOM service uses most of the output of the previously discussed DICOM services and generates web reports that can be viewed from the EMR (Figure 3a).

EPICore application

Because all calculations for large-scale 2D portal dosimetry are automated and the results are stored locally, the only user intervention is the examination of the PDIs and gamma images from the central PACS database. Besides the web reports, an application called EPICore is developed on top of the PACS system to view, evaluate and annotate the portal dosimetry results (Figure 3b).

Results

In our department, about 2000 patients are treated each year with a curative intent. Using 2D portal dosimetry, approximately 12500 and 35000 treatment fields are imaged pre-treatment and during treatment,



(a) (b)

Figure 3: (a) Web report image from the trend analysis DICOM service with multiple gamma images in time calculated from portal images taken during the treatment of a patient with stomach cancer. The colors red and blue mean that dose differences and distance-to-agreement do not fulfill gamma criteria of 5% and 5 mm. (b) Screenshot of the gamma image evaluation screen in EPICore, showing a transit gamma image acquired during an IMRT treatment in the head and neck region.

respectively. For clinical 2D portal dosimetry, about 350000 images per year and 600 images per day are handled by our technical infrastructure.

The clinical reliability of the technical infrastructure for 2D portal dosimetry is estimated to be better than 99%.

Discussion and conclusion

In this work, it is shown that large-scale 2D portal dosimetry is possible with a minimum number of user interventions and within acceptable image handling times using the technical infrastructure. The workflow has a high clinical reliability and its clinical application substantially increases the accuracy of patient treatments.

Due to the modular design of the technical infrastructure using DICOM services, it is relatively easy to extend the 2D portal dosimetry workflow to a 3D and even 4D (time-resolved) workflow.

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