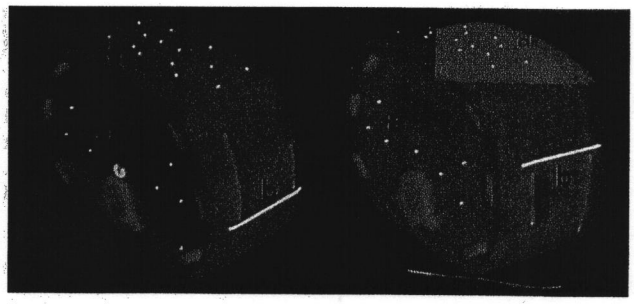

Fig. 1 *Left* phantom frontal view. *Right* phantom back view. **a** Metallic nipple markers and **b** Metallic wire markers over phantom surface

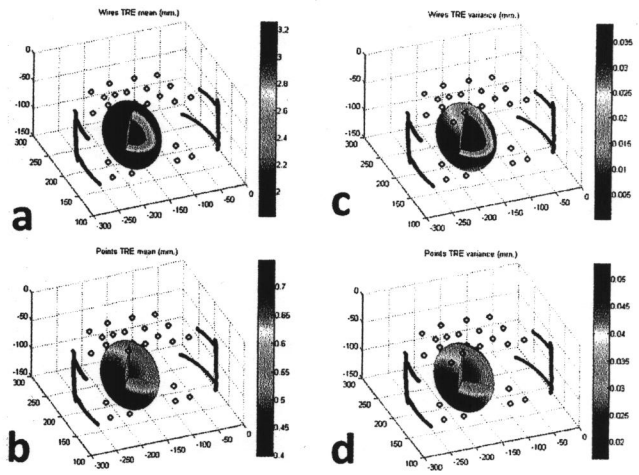

Fig. 2 **a** TRE mean for line-based registration (mm); **b** TRE mean for point-based registration (mm); **c** TRE variance for line-based registration (mm) and **d** TRE variance for point-based registration (mm). Metallic nipple positions (*red dots*) and metallic wire markers positions (*blue lines*) over the phantom surface

Iterative Closest Point (ICP) [4]. Thus, we obtained 12 point-based and 12 wire-based registration matrices. For each registration matrix we calculated the estimated Target Registration Error (TRE) [5] along an area of interest (50 mm radius ball). We also obtained the mean and variance of TRE in 12 different repetitions with the purpose of comparing wire and point-based schemes.

Results

Figure 2 shows the TRE average and variance along the 12 repetitions in the area of interest, with values that increase with the distance from the center of the ball. The maximum TRE is 3.3 mm for wire-based registration and 0.8 mm for the point-based scheme. Mean record time for positioning was 54 s and 4 min for wire and nipple markers respectively.

Conclusions

The feasibility of using wire markers in order to obtain the registration parameters has been demonstrated on a phantom study. The variance values of the TRE suggest that the proposed wire-based registration scheme is robust, and quite faster in terms of position recording time. The accuracy, as measured by TRE in the area of interest, is lower than in the standard point-based solution. This was expected since the position of the wire markers is not optimum, but fulfills the requirements from the real scenario. The nipple markers provide the best possible solution, since they completely surround the area of interest, but their location is impossible to achieve in the clinical setting. The proposed scheme allows radiation oncologists to know the real applicator position during IOERT procedure.

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Evaluation system for electronic retrospective analyses: optimization of treatment algorithms for locally advanced pancreatic cancer

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Purpose

In radiation oncology recurrence analysis is an important part in the evaluation process and clinical quality assurance of treatment concepts. With the example of patients with locally advanced pancreatic cancer we developed and validated interactive analysis tools to support the evaluation workflow. Furthermore, we analyzed weekly CTs performed with an in-room CT-scanner during intensity-modulated radiotherapy (IMRT) to asses changes in the gross tumor volume (GTV) as well as adaptive radiotherapeutic (ART) approaches.

Methods

A total number of 783 patients with pancreatic cancer have been documented into a professional, web-based documentation system. Information about radiation therapy, diagnostic images and dose distributions have been imported. We randomly choose 9 patients with disease progression after neoadjuvant chemoradiation for recurrence analysis and 10 patients for GTV volume comparison.

We designed and established an analysis workflow. After automatic registration of the radiation planning CTs with the follow-up images, the recurrence volumes of 9 patients were segmented manually. Based on these volumes the DVH (dose volume histogram) statistic was calculated, followed by the determination of the dose applied to the region of recurrence and the distance between the boost and recurrence volume.

For 10 patients treated with IMRT (54 Gy in 25 fractions) with an integrated boost we manually matched weekly CT scans with the planning CT scan. We delineated the GTV as well as the organs at risk (OAR), especially the right and left kidney. The intersection of the initial GTV volume compared to GTV volumes during treatment, and separate dose statistics were calculated and used for comparison.

We determined dose to OAR with focus on the kidneys without ART-compensation and re-planned based on the weekly acquired CT scans to evaluate dose to OAR.

Results

For the recurrent patients, 3–7 registrations were calculated in one step. Compared to a manual approach enormous time saving can be expected. We calculated the percentage of the recurrence volume within the 80 %-isodose volume and compared it to the location of the recurrence within the boost volume, boost + 1 cm, boost + 1.5 cm and boost + 2 cm volumes. Recurrence analysis demonstrated that all recurrences except one occurred within the defined GTV/boost volume; one recurrence developed beyond the field border/outfield. With the defined distance volumes in relation to the recurrences, we could show that most recurrent lesions were within the 2 cm radius of the primary tumor. Two large recurrences extended beyond the 2 cm, however, this might be due to very rapid growth and/or late detection of the tumor progression.

Over time, changes in GTV volume were only minor and non-significant in all cases. Initial GTV volume ranged from 47.7 to 151.8 ml and volume changes during treatment from 74 to 109 %. GTV volume changes have little impact on dose application. Whereas, organ and tumor deformation were observed. After manual matching, good concordance of bony structures; soft-tissue organs, however, showed significant motion over time. With adequate margins, normal tissue constraints to OAR can be kept, but dose to OAR can be most effectively used with ART for compensation of daily movement.

All results are stored in the database of the documentation system and are reusable as new input for further calculations. Export of all data can be easily done as a CVS file (Comma-Separated Values) at any time. To allow this, a GUI-based (Graphical User Interface) SQL query builder has been implemented. These queries can be saved and reused for a continuous overview on the data.

Conclusion

The main goal of using automatic analysis tools in an evaluation system is to reduce time and effort conducting clinical analyses, especially with large patient groups. We showed a first approach and use of a semi-automated workflow for recurrence analysis, which will be continuously optimized, and how analysis tools can be used for volume comparison. Further steps need to be taken to enhance automation and connect the analysis tools to our documentation system.

In conclusion, despite the limitations of the automatic calculations we contributed to in-house optimization of subsequent study concepts. However, already it has become apparent that the benefits of digital data management and analysis lie in the central storage of data and reusability of the results. Therefore, we intend to adapt the evaluation system to other types of tumors in radiation oncology.