Purpose or Objective: A tool for fast dose distributions analysis in hadrontherapy is presented, which integrates on GPU a Fast Forward Planning (F-FP), a Fast Image Registration algorithm (F-IR), a Fast Gamma-Index (F-GI) and Fast DVH computations. The tool will be interfaced with the dose delivery system (DDS) of a synchrotron-based facility to investigate the feasibility to quantify, spill by spill, the effects of organ movements on dose distributions during 4D treatment deliveries.

Material and Methods: The F-FP was built by porting to CUDA the PlanKIT TPS, developed by INFN and IBA for proton and carbon scanned beams. The feature of choosing, among the 4DCT volumes, the CT volume corresponding to a specific respiratory phase (CT-phase) was added. To evaluate target movements, the 4DCT images are pre-processed (using C++ algorithms) to obtain the deformation vector fields. The F-IR uses the latter to map the dose calculated on a CT-phase to the CT volume used to plan the treatment (CT-reference). The F-FP runs twice to calculate in parallel the planned dose (on the CT-reference), and the delivered dose (on the CT-phase mapped on the CT-reference by the F-IR). Finally, the comparison between the two dose distributions is performed through fast F-GI and DVH computations to quantify the dose deformation due to intra-fraction anatomical changes. The NVIDIA Tesla K40c in a Workstation (WS) HP Z820 (2xIntel XeE5-2670v2) was used. The WS will be interfaced with an optical tracking system (OTS) to test the DDS and OTS. The preliminary results suggest its possible use to on-line quantify the effects of target movements during 4D treatment deliveries with scanned proton and carbon ion beams.

Results: A preliminary version of the F-FP has been tested for physical and biological doses for protons and carbon ions, showing total execution times within 1 s, and negligible absolute differences (<10^-4 Gy) compared with PlanKIT results. The F-GI and DVHs computation times are of the order of few ms, while the F-IR will be within 1 s. The times for data transfer are negligible. The overall system operations and the execution times are summarized in Fig 1.

Conclusion: A GPU-based tool for dose distributions analysis in hadrontherapy has been developed and will be interfaced with clinical DDS and OTS. The preliminary results suggest its possible use to on-line quantify the effects of target movements during 4D treatment deliveries with scanned proton and carbon ion beams.
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Intraoperative radiotherapy with electrons in breast cancer patients with cardiac devices.
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Purpose or Objective: To evaluate the feasibility and the safety of delivering intraoperative radiotherapy (ELIOT) to the tumor bed in breast cancer patients with cardiac implantable electronic devices as part of breast conserving treatment. Cardiac devices, as pacemakers or defibrillators, can suffer from malfunctions as a result of exposure to ionizing radiation. Scattered radiation can be harmful as direct radiation as well. Measurements of absorbed dose during ELIOT in the subclavicular region supposed to house cardiac implantable electronic devices were carried out in healthy patients without heart disease. The aim of the study is to verify that the intraoperative dose does not exceed the recommended maximum dose of 2 Gy.

Material and Methods: The present analysis was performed on 18 out of 25 patients considered for the study. After signing the informed consent, all patients underwent breast conserving surgery. After tumor removal and before delivering ELIOT to the tumor bed, two catheters, each of them containing 8 thermoluminescent dosimeters (TLDs), were placed. The first catheter, the internal one, was attached to the thoracic shielding (an aluminum-lead disk of 7.8 cm in diameter) and became an integral part of it. The shielding was located beneath the reconstructed breast parenchyma of the tumor bed, to minimize the dose to underlying tissues and its tip was positioned in the subclavicular region, where cardiac devices are supposed to be. The second catheter, the external one, was placed on the skin, parallel to the first one, next to the applicator (4.5 cm of diameter, 15° beveled). The TLD reading showed the absorbed dose due to the scattered dose correlated to the distance from the applicator.

Results: Given a prescribed dose of 21 Gy at 90% isodose, the external TLDs on the skin read a mean dose of 0.32 Gy (range, 0.10 - 0.55 Gy), measured starting 1.5 cm from the applicator wall up to 10.5 cm. By evaluating the doses measured by TLDs in the internal catheter, the minimum distance considered safe for cardiac devices was found to be 2.5 cm from the applicator wall. No correlation with tumor site and electron energy was observed. When clinically indicated, ELIOT might be a valid alternative to external irradiation, which is conditioned by the low threshold dose for cardiac devices, as recommended by current guidelines.

Conclusion: Final results are not available yet, as the study is ongoing. However, on the basis of analyzed data, ELIOT seems to be safe for patients using cardiac devices as long as the minimum distance of 2.5 cm is kept between the cardiac device edge and the applicator wall. No correlation with tumor site and electron energy was observed. When clinically indicated, ELIOT might be a valid alternative to external irradiation, which is conditioned by the low threshold dose for cardiac devices, as recommended by current guidelines.