Translating Hybrid Imaging for Interventions: Intra-operative Guidance and Evaluation using 2D and 3D Interventional X-ray Scintigraphy Imaging

Reporting

Project Information

IXSI3D
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Project website

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Periodic Reporting for period 2 - IXSI3D (Translating Hybrid Imaging for Interventions: Intra-operative Guidance and Evaluation using 2D and 3D Interventional X-ray Scintigraphy Imaging)

Reporting period: 2017-06-01 to 2018-11-30

Summary of the context and overall objectives of the project

This project is about design, development, technical evaluation of the hybrid C-arm that is capable of acquiring nuclear images and x-ray images at the same time, giving real time fused images. The device is to be clinical evaluated in the context of radioembolization.

Problem:
Treatment of cancer is increasingly performed in a minimal invasive fashion guided by imaging, as an alternative to open surgery. The advantage of minimal invasive interventions are less complications, better quality of life, less costs, more targeted. One example of image guided minimal invasive intervention is the treatment of liver cancer using radio-embolization. This is specific advantages over surgery, including less side-effects and faster recovery of the patient.

For image guidance of these therapies commonly a traditional C-arm is used that allow real time monitoring of the intervention using fluoroscopic x-rays. These x-rays show the patients anatomy and the surgeons tools. The C-arm geometry allows for easy integration of the imaging modality in the operation theatre.

One major development in medical imaging of the last decade is the introduction of multimodality or hybrid modalities like PET/CT, SPECT/CT and more recently the PET/MRI. The success of these modalities is based on the fact they combine anatomical imaging with functional or molecular imaging. These hybrid modalities are used for diagnosis of cancer and monitoring of cancer treatment. It would potentially be very advantageous if these modalities would be available for guidance of interventions, however the modalities lack the flexibility of the C-arm for easy integration in the operation theatre.

The objective for that reason is the research and develop new hybrid modality that has the right features to guide and improve minimal invasive interventions. The core objective is to achieve personalized medicine using radio-embolization by patient tailored dosimetry in the intervention room.

Importance for society.
The global burden of cancer continues to increase. In the Netherlands alone, every year almost 100,000 people are diagnosed with the disease. Medical imaging’s main role in oncology is diagnosis and guidance during therapy. Recently introduced hybrid systems like PET/CT already have proved to be very effective in early diagnosis and follow-up after treatment. The combination of sensitive molecular information and exquisite anatomical content make hybrid images easy to read, with high sensitivity and specificity. At its introduction, success was not obvious and questions were raised about the added value of combining two existing modalities. However, helped by the familiarity every health care specialist has with x-ray imaging, hybrid systems have skyrocketed the appreciation, application and commercial success of nuclear imaging.

A relatively new application of medical imaging is image guided oncological intervention. Instruments are inserted via small openings and using live (x-ray) imaging guided to the tumor for local treatment. The procedure benefits include less pain, less scaring, shorter hospital stay and higher accuracy rate. So far, the procedures rely on (x-ray) anatomical imaging for guidance. In this proposal I argue that the positive impact hybrid imaging recently had on diagnosis will proof to be applicable to minimal invasive oncological procedures such as radioembolization. Candidates for this treatment are the yearly 10,000 patients in the Netherlands with primary or metastatic liver cancer, indicating the potential significance of this project. Other application areas include the removal of parathyroid (and other) tumors in minimal invasive surgery, performed approximately 10,000 times per year in the Netherlands. X-rays are used in mammography and guidance of (breast) biopsies. Here combination with nuclear imaging may significantly improve sensitivity and specificity of diagnosis, while success rates of biopsies may be improved with hybrid ima...
Period 1 dec 2015 – June 2017
The project started with the first conceptual prototype as suggested in the proposal: we placed 4 gamma cameras around the x-ray tube so that the cameras could form a stereoscopic image that could be reconstructed so that it always overlapped with the x-ray image. This system was simulated in constructed in a physical prototype. Using this, image quality was evaluated for different collimators of the set-up, a calibration procedure was developed and the potential of the conceptual design to perform relevant personalized dosimetry. The latter indicated that the important adverse effect of hazardous shunting of radioactive particles to the lungs can be detected using our hybrid C-arm. One other objective of the proposal is to implement methods to compensate for respiratory motion, which may substantial hamper the accuracy of the personalized dosimetry. This was researched and indicated the need of motion correction schemes to be included in our system.

During this period, as alternative to the original concept of 4 gamma cameras around the x-ray tube, a second concept was formulated, that places the gamma camera behind a x-ray flat panel detector and relies on the fact the x-ray is detector is mainly sensitive for the x-ray photons and partial transparent to the gamma photons. The gamma is equipped with a cone beam collimator so guarantees perfect overlap of the x-ray and nuclear images. For this a new prototype was constructed with the help of Philips Medical Systems. This company showed interest in our work and decided to support it with knowledge about x-ray imaging and by making x-ray parts available on loan for the project.

Period 2 July 2017 – June 2018
During this period the prototype was further developed to show case its ability to do live x-ray/nuclear imaging in 2D and also in 3D. The live 2D experiments were documented and submitted to radiology, which has recently decided to consider publication if certain criteria could be met (major revision). For the 3D part, reconstruction algorithm needed to be developed, implemented and evaluated. We have also shown that dosimetry is even possible at very low levels of radio-activity. As indicated by the work in the previous period, motion of organs is a detrimental factor in (quantitative) imaging. This can be compensated by exploiting the specific x-ray and nuclear capabilities of our concept as we have reported. Since in the interventional setting time is even more of critical factor as in the diagnostic setting we also investigated the possibilities of speeding up the acquisition. Especially when lung shunting is to be evaluated the acquisition can be as short as 1 minute.

Besides reconstruction and simulations, we have also worked on the hardware, mainly the performance of the detector. We have researched the impact of the x-ray flux on the gamma camera and concluded this may be a limiting factor in the selection of the optimal x-ray protocol. Solutions for this problem are to be found in electronic gating and filtering of the raw PMT signals from the scintillation gamma camera, the use of dedicated scintillation crystals (CeBr3) or the use of a semiconductor (CZT) gamma camera. Both de CeBr3 crystal and the CZT detector are relatively new and therefore very costly and is considered to be outside the budget of our project. Therefore the clinical prototype will be constructed using a classical gamma camera, if necessary equipped with electronic gating and filtering. In addition an off-focus placed collimator was investigated that substantially lowers the flux of x-ray photon seen by the gamma camera, at the cost of a slight miss-registration between x-ray images and nuclear images.

In addition to the scientific work, a lot of our efforts is currently put in the realization of the device and it’s clearance for medical application. This latter requires the composition of a Medical Device Dossier including a large set of safety and quali
The current state of the art in hybrid imaging is found in clinical and conceptual PET/CT, SPECT/CT and PET/MRI. Although they are in constant development, and improves are introduced by all major companies on a regular basis and the impact of these scanners is indisputable, these scanners however are dedicated to the diagnostic setting. No device exists yet that effectively makes the benefits of hybrid imaging available in the interventional setting. The purpose of this project is therefore to accomplish a hybrid C-arm that has the right features for interventional use.

As described earlier, we have made substantial progress in realizing this objective. We have conceived an innovative dual-layer detector capable of acquiring both x-ray as nuclear images simultaneously and perfectly registered, all required for seamless integration in the intervention or operation theatre. We have simulated the device to evaluate technical aspect and build a working prototype to show case in reality. To support 3D imaging we have developed algorithm to convert data from the hybrid dual layer detector into quantitative 3D images, necessary for personalized dosimetry. In addition we shown that limitation of the dual-layer concept in x-ray flux and image quality can be mitigated using relatively simple adaptations to a standard clinical gamma camera.

The expected result at the end of the project, is that our technology has been integrated in a clinical grade C-arm construction that complies with all regulations and be tested in a clinical pilot study. So far we are still on track to realize this final objective as laid in the initial proposal.

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