FIRST EXPERIENCE WITH COMPUTER-ASSISTED LAPAROSCOPIC NEEDLE GUIDANCE FOR PANCREATIC TUMOUR ABLATION IN A PIG

Benjamin Eigl[1 2], I. Paolucci[1], T. Rudolph[2], A. Garcia[3], E. Serra[3], S Weber[1], Mariano Gimenez[3]

[1]ARTORG Center for Biomedical Engineering Research, University of Bern, Bern, Switzerland
[2]CAScination AG, Bern, Switzerland
[3]Institut de Chirurgie Guidée par l'Image, IHU, Strasbourg, France

Contact: benjamin.eigl@artorg.unibe.ch
mariano.gimenez@ihu-strasbourg.eu

Introduction:

Pancreatic cancer is the deadliest of the gastrointestinal tract with 5-year survival rates of less than 5% [1]. *Irreversible electroporation (IRE) is an ablation technique that spares vessels and is therefore suitable for treatment of locally advanced and unresectable pancreatic cancer* [2], [3]. *Placing these needles resembles a major challenge especially if the tumour is located nearbystructures at risk such as the aorta, vena cava and portal vein. Herein, we present the result of an animal study where we evaluated the applicability of computer-assisted planning and navigation for pancreatic tumour ablation using a single needle in a laparoscopic setting. Furthermore, we conducted the CT imaging with and without pneumoperitoneum and compared the registration outcome. This work serves as a basis to investigate the applicability of our proposed workflow for the future IRE use cases with multiple needles*

Methods:

The test site (IHU Strasbourg, France) consisted of a CT Scanner (Somatom Force, Siemens), a navigation system (Cas-One, CAScination), and a laparoscopy system (Karl Storz). The animal was under general anesthesia and for the study two artificial tumours were inserted percutaneously into the liver and the pancreas body with the guidance of an interventional radiology system (CAS-One IR). Next, two CT scans were performed with and without pneumoperitoneum to evaluate the fiducial registration error (FRE) during the intraoperative navigation which resembles the quality of the point-based registration. In addition, the distance to the placed tumors after navigation and the time needed for the registration attempts were tracked and evaluated. Our proposed workflow consists of two steps which are described as follows.

- **Pre-operative planning**

The CT scans were performed under apnea with 30 mm/Hg pressure and segmented using a commercially available software (Myrian, Intrasense), specifically targeted for segmentation of abdominal structures like the liver and pancreas parenchyma with tumours, aorta, vena cava and portal vein. The data were imported into the navigation system and the planning of a needle for each tumor was conducted using the developed planning solution (see Figure 1). The software gives the surgeon the ability to pre-operatively define targeting strategies using the CT image data and 3D reconstructions. In our use case a single needle was planned to evaluate our proposed workflow by means of targeting accuracy and overall feasibility. In previous work we have shown the potential of the 3D planning for multiple needles in pancreatic IRE treatments as it provides the surgeon the possibility to better prepare for the upcoming procedure.

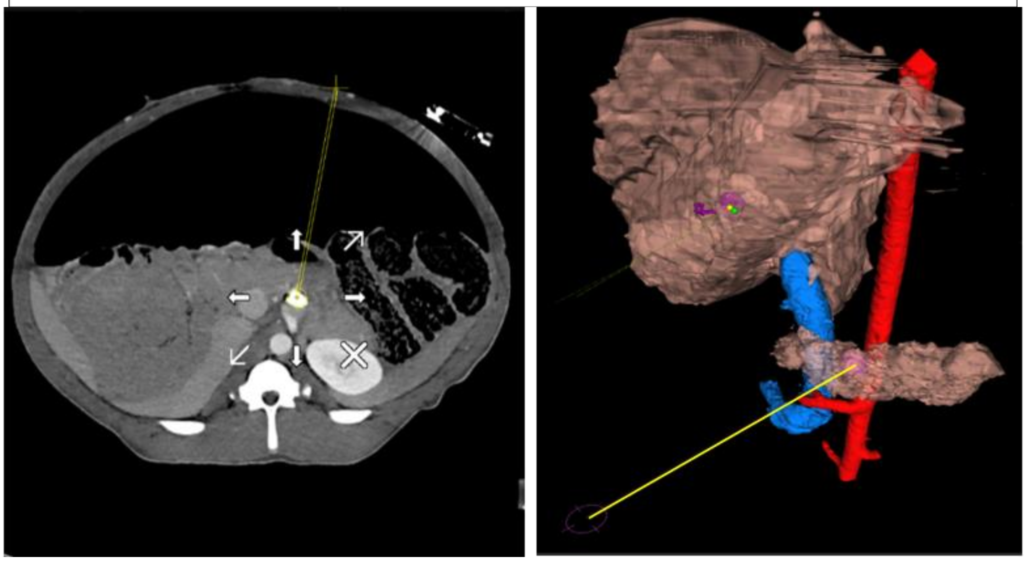

Figure 1: CT scan (pneumoperitoneum) and 3D reconstruction with planned trajectory

- **Intra-operative navigation**

Using the planning data, the surgeon can perform a rigid registration using surface landmarks acquired by an optically tracked instrument. A rigid pointer with the length of 350mm was attached with a marker shield and calibrated. For evaluation, four corresponding point pairs were acquired on the organ surface of the liver (2), pancreas (1), and spleen (1). The landmarks were chosen after the surgical exploration. The developed software allows the surgeon to define points on the CT image data as well as on the 3D reconstructions. The software tracks relevant data related to the acquisition attempts and re-calculates the FRE once a new point pair is acquired. The outcome is used to compare the conventional and pneumoperitoneum approach. Once a rigid transformation is calculated, the defined and acquired points are visualized in the 3D scene to give the surgeon a visualization of possible outliers.
For the needle placement the CT scan with pneumoperitoneum was used under live endoscopic ultrasound control and the animal was put under apnea during the insertion process. The needles were placed according to the planned 3D trajectory and the distance to the target was evaluated using the endoscopic ultrasound.

Figure 2 Intraoperative setup

Result:

The registration workflow was conducted twice (CT scan with and without pneumoperitoneum) with three registration attempts each. When registering the non-insufflated scan, the mean FRE was located at 15.6mm with an average of 4 minutes per registration attempt. These numbers decreased for the pneumoperitoneum approach with a mean FRE of 8.7mm and an average time of 3 minutes per registration attempt.

The targeting of the liver tumour was conducted using the pneumoperitoneum approach and resulted in a displacement of the needle to the tumour center by < 20mm while the second attempt was considered as successful (< 10mm). Between these attempts the point pair acquired at the spleen was filtered out of the registration which resulted in a better registration around the region of interest. The same misplacement was also observed during the targeting attempt of the pancreatic tumour where the misplacement during the first attempt was even larger with < 30mm. The second attempt resulted in a slightly decreased misplacement to < 20mm, yet the accuracy was not as good as the targeting approach of the liver tumour.

Discussion & Conclusion:

In this work, we presented the feasibility of a computer-assisted planning and navigation approach for the placement of ablation needles in the liver and the pancreas. The planning enables the surgeon to pre-operatively define targeting strategies based on the 2D and 3D image data and thus better prepare for the upcoming procedure. Intraoperatively, we investigated that the system assists the surgeon to localize the tumour during the surgical exploration. It can be stated that for an accurate targeting according to the pre-operatively defined plan multiple factors must be considered. First, the CT scan with the pneumoperitoneum enabled better registration which was an expected result but is not easy to accomplish due to the small number of hybrid operating rooms. The conventional method still provides a sufficient registration result for the localization of the tumours. It needs to be said that one part of the improvement between the conventional and pneumoperitoneum approach can be explained that the surgeon became more familiar with the workflow. Furthermore, landmarks near the region of interest result in a better registration. The larger misplacement in the pancreatic targeting approach can be explained by the location of the registration points closer to the region of the tumour in the liver. Therefore, the navigation solution enables the surgeon to acquire as many point pairs as necessary and provides the possibility to filter out certain pairs. This allows to easily adjust the registration for each tumor in case they are located at different spots. Beside the surface landmarks an ultrasound-based approach to acquire landmarks on internal structures need to be considered, especially in the pancreatic use case. We are currently working on the solution to track the laparoscopic ultrasound using electromagnetic tracking. One of the major challenges resembles the freehand navigation to follow the planned trajectory. Therefore, an approach with a tracked aiming device, commonly used in interventional radiology, will be investigated in the future.

In respect of the usage of multiple needles used for the IRE procedure we see a large potential for this workflow to, on the one hand allow the surgeon to pre-operatively define the IRE strategy, and on the other hand to assist during the needle placement while considering different constraints such as parallelism, spacing between the needles and anatomical structures at risk. Finally, this solution shall enable more minimally-invasive IRE treatments for patients with locally advanced, unresectable pancreatic cancer.

[1] R. L. Siegel, K. D. Miller, and A. Jemal, “Cancer statistics, 2017,” *CA. Cancer J. Clin.*, vol. 67, no. 1, pp. 7–30, Jan. 2017.

[2] G. Narayanan, “Irreversible Electroporation.,” *Semin. Intervent. Radiol.*, vol. 32, no. 4, pp. 349–55, Dec. 2015.

[3] G. Narayanan *et al.*, “Percutaneous irreversible electroporation for downstaging and control of unresectable pancreatic adenocarcinoma.,” *J. Vasc. Interv. Radiol.*, vol. 23, no. 12, pp. 1613–21, Dec. 2012.