Automated Process to Generate Patient-Specific 3D Printed Molds for Histological Validation and Guided Fresh Tissue Procurement

Cody Bastian[1], Marcial Garmendia-Cedillos[1], Raisa Freidlin[1], Jonathan Krynitsky[1], Julian Custer[3], Vladimir Valera Romero[3], Sherif Mehralivand[2], Maria J. Merino[4], Peter A. Pinto[3], Peter L. Choyke[2], Baris Turkbey[2], Tom Pohida[1]

[1]Center for Information Technology, Signal Processing and Instrumentation Section : [2]National Cancer Institute, Molecular Imaging Program

[3]National Cancer Institute, Urologic Oncology Branch : [4]National Cancer Institute, Laboratory of Pathology

Abstract

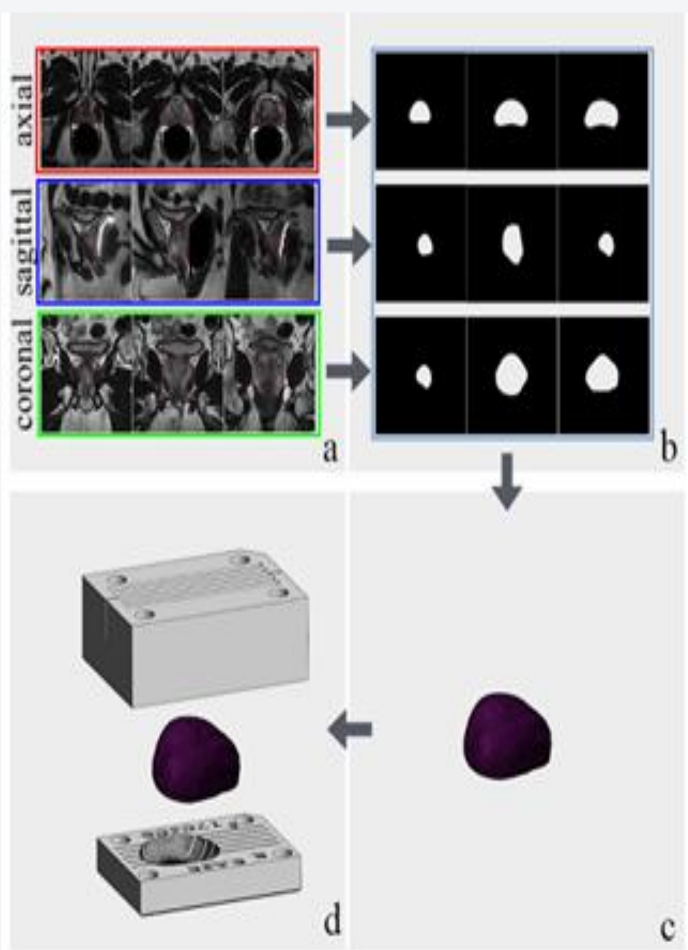
The Signal Processing and Instrumentation Section is collaborating with the NCI to develop novel methods and devices to assist in the localization and procurement of lesions within a resected prostate. By using DICOM images, Volumes-of-Interest (VOIs) files, and 3D computer-generated models provided by NCI staff, our team at SPIS can generate a 3D printable patient-specific prostate mold to preserve *in vivo* orientation and shape of the gland with cutting slots correlated to MR slices. The 3D printed mold holds the prostate gland in place and assists surgeons with guided procurement of fresh tumor tissue. Originally, the tumor samples were obtained using the cutting slots, which coincide with the imaging planes, to access the area of the lesion. Project development led to a guided needle biopsy method to minimize damaging to surrounding tissue. The prostate mold generation process is automated using Solidworks, and we are working toward an implementation using an open source software platform to ease method dissemination.

Background

Prostate cancer is one of the most common types of cancer among American men. Tumor tissue procurement is a critical component of prostate cancer research. Tissue used for research must be gathered and preserved shortly after resection. To minimize degradation of the tissue molecular integrity, the surgeon only has a short period of time to locate, access, and procure the tumor tissue. The migration from the knife slot method to the guided needle biopsy method offers increased precision, reduced time, and decreased surrounding tissue damage.

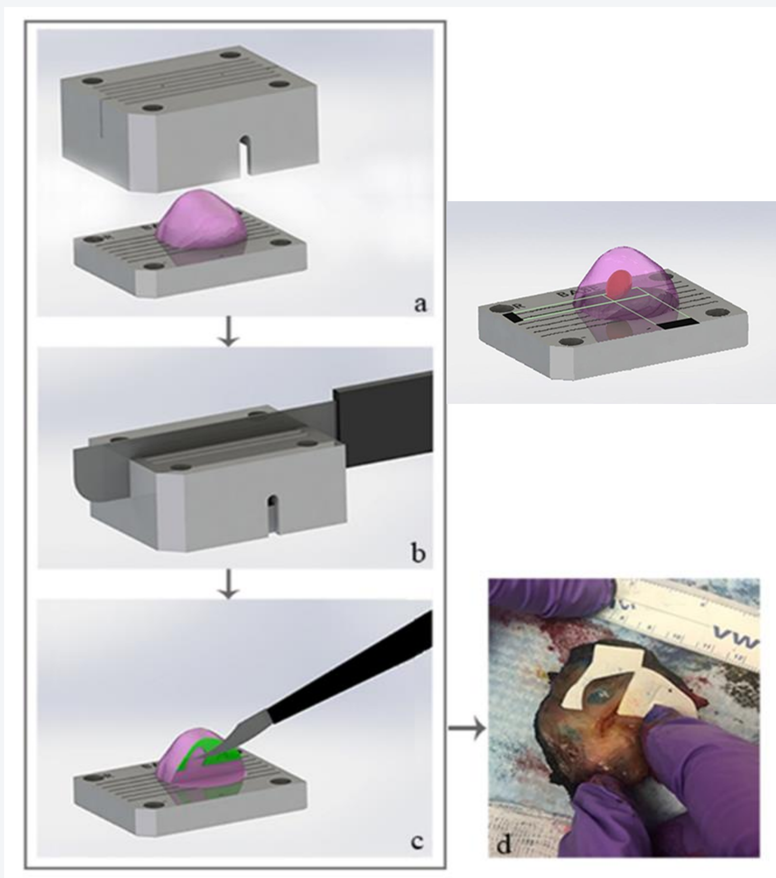
Mold Generation

We utilized the computer aided design (CAD) software, SolidWorks, to develop the mold for fresh tissue procurement procedures and gland processing in the pathology lab. By taking advantage of SolidWorks' API and the macro recorder feature, we were able to develop a code that automates the process for producing the patient specific molds. The program automatically reads through the DICOM, STL, and VOI files of organs and lesions (prostate, tumor regions, and urethra) provided by our collaborators at the NCI. Additionally, predefined parameters (cutting slot spacing, margins around prostate gland, tumor cut depth, etc.) ensures repeatability for each generated mold. The molds are fabricated in ABS plastic using an FDM 3D printer, taking about 10-24 hours to print. ABS plastic is ideal due to its low cost, durability, and rigidity. Finally, a 3D pdf assembly model is also provided to aid the surgeon in planning and conducting the tumor fresh tissue procurement.



Procurement Methods

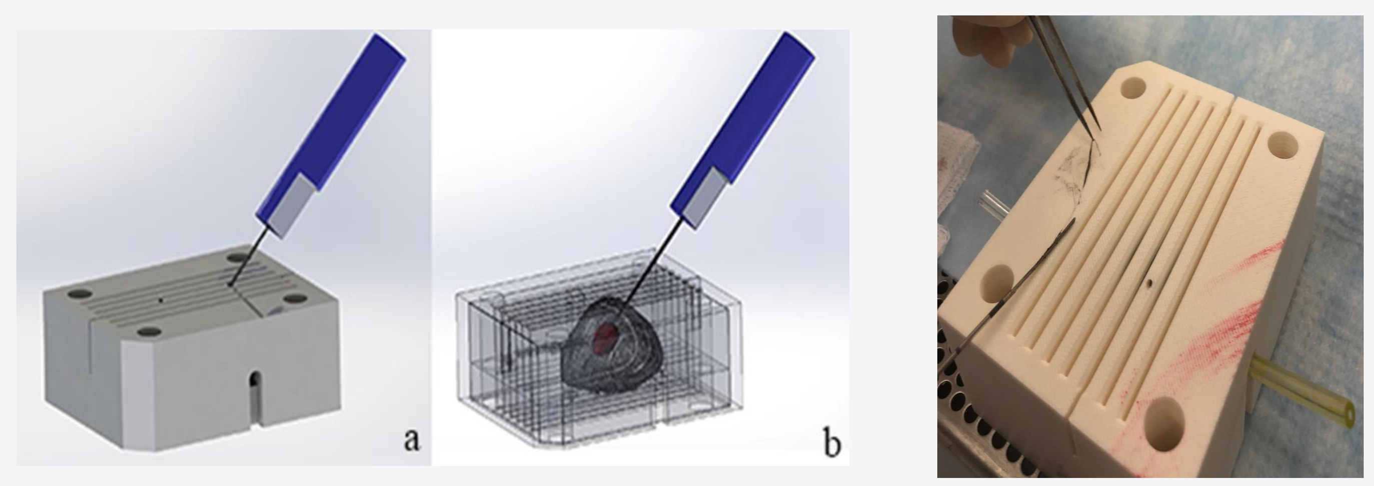
Knife Slice Method



The knife slice method uses VOI files to determine the center of the tumor. A mold procurement access slot is positioned based on the closest cutting slot parallel to the center of the tumor to avoid additional cuts. In addition, knife-guiding procurement slot eliminates depth uncertainty. Lesion localization is achieved with the locator card. The perimeter shape of the locator card is determined by the profile of the segmented prostate gland in the plane of the access cut. The outline (i.e., void) of the lesion within the card corresponds to the segmentation performed by an experienced radiologist. After the locator card is inserted into the access slot, a tissue sample is obtained through the card opening (Shown in figure 3d). A significant challenge with this method is that a large part of the gland must be cut in order to obtain the tumor tissue sample.

Needle Biopsy Method

The implementation of the guided needle biopsy method provides a more convenient and effective technique to procure tumor tissue, as well as reduces damage to the gland. Catheter tubes are inserted into the urethra for improved gland positioning and stability. Two 45-degree angle needle holes which pierce the center of the tumor are incorporated to guide the needle for improved biopsy precision. Finally, a plastic sleeve is placed over the needle for depth control. During the procurement process, this method allows the surgeon to easily access the tumor without the need for cutting through the gland.



Movement Towards Open Source

Utilizing expensive CAD software to generate the molds limits the dissemination of our methods to other groups. A functionally equivalent implementation utilizing open source CAD software should improve access to a larger community. We have selected the open source CAD software Blender for future developments. Blender is a free to use software that offers similar 3D design and modeling capabilities to SolidWorks. Additionally, the corresponding python API gives access to other capabilities, such as: DICOM dataset metadata reading, advanced image analysis tools, and MRI image viewing. Currently, DICOM metadata is read using another software, ImageJ, and then imported to SolidWorks. Blender will enable consolidation of the entire process within a single software platform. This transition to an open source implementation should enable other research centers to duplicate our methods and corresponding research.

Conclusions and Future Work

A significant challenge in this project is that MR images of patients are usually taken several months prior to the resection of the prostate gland. During this time delay, the prostate could change size and shape, which are difficult to predict. Therefore, the mold will not be a perfect fit in such cases. Additionally, there may be slight positioning errors (e.g., rotation) when the gland is placed inside the mold. Our mold generation process is fully automated. However, we occasionally find unique cases that require manual corrections. Future work will complete the transition to the open source software Blender to facilitate method dissemination to outside research centers.

References

Turkbey B, Mani H, Shah V, Rastinehad AR, Bernardo M, Pohida T, Pang Y, Daar D, Benjamin C, McKinney YL, Trivedi H, Chua C, Bratslavsky G, Shih JH, Linehan WM, Merino MJ, Choyke PL, Pinto PA (2011). *Multiparametric 3T prostate magnetic resonance imaging to detect cancer: histopathological correlation using prostatectomy specimens processed in customized magnetic resonance imaging based molds.*

Vijay Shah, Thomas Pohida, Baris Turkbey, Haresh Mani, Maria Merino, Peter A. Pinto, Peter Choyke, Marcelino Bernardo (2009). *A method for correlating in vivo prostate magnetic resonance imaging and histopathology using individualized magnetic resonance -based molds.*

An Elen, Sofie Isebaert, Frederik De Keyzer, Uwe Himmelreich, Steven Joniau, Lorenzo Tosco, Wouter Everaerts, Tom Dresselaers, Evelyne Lerut, Raymond Oyen, Roger Bourne, Frederick Maes, and Karim Hautermans (2016) *Validation of an Improved Patient-Specific Mold Design for Registration of In-vivo MRI and Histology of the Prostate*