A COORDINATE REGRESSION-BASED DEEP LEARNING MODEL FOR CATHETER TRACKING IN CARDIAC INTERVENTIONS

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Introduction

Globally, transcatheter cardiac procedures are increasingly being performed to treat a wide variety of structural heart defects. Despite being minimally invasive, these procedures are nonetheless still responsible for a wide range of complications in the post operative period.

Table 1. Common Transcatheter Interventions and Their Complication Rates.

Type of Defect	Treatment Procedure	Cases performed	Rates of complications
Septal defects	Ventricular septal defect repair (VSD)	7500 open surgeries and catheter repairs conducted annually in the USA (2018)	2.9–8% of patients present with severe complications
	Atrial septal defect repair (ASD)	Over 240,000 procedures have been done globally to-date (2015)	Overall rate of complication is very low (<1%), however valvular damage can be seen in 10-37% of procedures
Patent foramen ovale (PFO)	PFO repair/closure	Over 230,000 procedures have been done globally to-date (2021)	7% of patients present with mild to severe complications
Left atrial appendage closure (LAA)	LARIAT	4,500 procedures conducted in the USA to-date (2018)	Up to 11.5% of patients experience mild to severe complications
	Watchman procedure	Over 10,000 procedures have been done globally to-date (2015)	1.5-2.8% of patients experience mild to severe complications
Valvular heart disease	Transcatheter mitral valve repair (TMVR)	10 000 TMVR procedures conducted in the USA to-date (2021)	10.25% of patients present with severe complications
	Transcatheter Tricuspid Valve Repair (TTVR)	TTVR is an experimental procedure with very limited operations taking place annually	9-11% of patients develop severe complications
	TAVI/TAVR	78 000 TAVI procedures conducted in the USA to-date (2021)	4-19% of patients present with severe complications

Our group aims to improve the clinical outcomes and accuracy of these transcatheter procedures by utilizing a novel image guidance program that utilizes fluoroscopy and MRI scans to track and guide the delivery catheters in these procedures.

Methods

My contribution within this study can be broken down into three stages:

Stage 1

During the first stage, I have drafted the manuscript for the research paper. Once complete, this manuscript is then submitted for publication.

Stage 2:

During this stage, I created the documents that are necessary for obtaining ethical approval for my study. This approval process was necessary to make the necessary changes to patient operative procedure.

Stage 3:

This final stage involved annotating and documenting images of the catheter taken from the lab. These image entries are utilized to train the deep learning program and improve its tracking capabilities

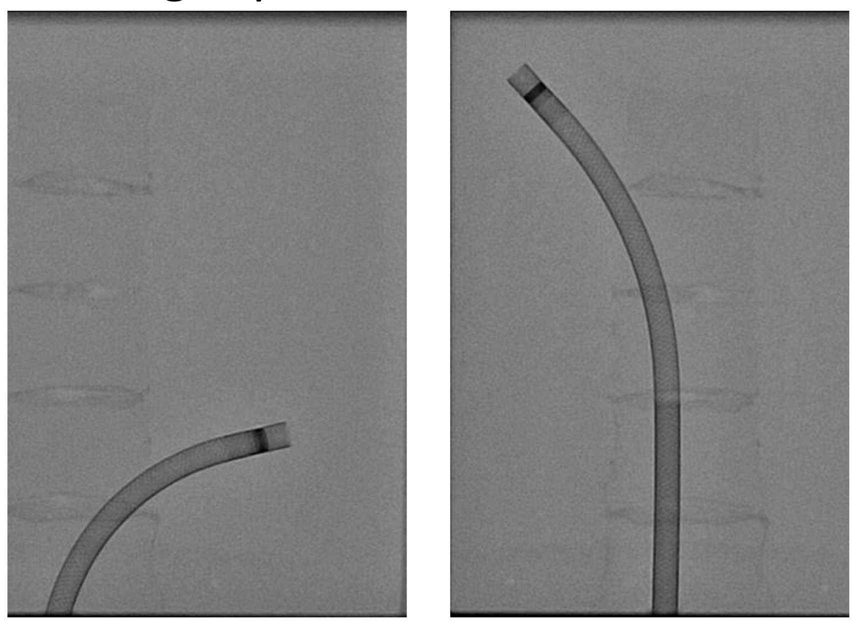

Figure 1. Examples of Images That Will be Annotated and Documented for Program Training

Results

This project aims to test a mixed reality visualization program to view its effect on the accuracy and safety of catheters during interventional cardiac procedures. To test the hypothesis, the study will be conducted on a cohort of 30 patients who are already enrolled into left atrial appendage, patent foramen ovale, or atrial septal defect occlusion procedures. Each of the subjects will undergo their preassigned procedure. The only deviation from standard practice will be the addition of ECG electrodes and respiratory monitors-which will be used to monitor and record intraprocedural vitals and identify whether the use of the imaging program does or does not compromise patient safety.

The image guidance system requires the patient to undergo a CT or MRI in advance of their procedure, this scan allows the creation of a 3-D model of the patient's heart. This 3-D model combined with intraprocedural fluoroscopy images of the catheter will be processed and analyzed by the program to generate a picture/hologram of the exact location of the catheter within the patient's heart. In practice, this hologram will then be visible to the operating physician via augmented/mixed-reality goggles. During the study, however, the doctor will not be shown these images so as not to interfere with their judgement and to ensure the results of the study are unbiased.

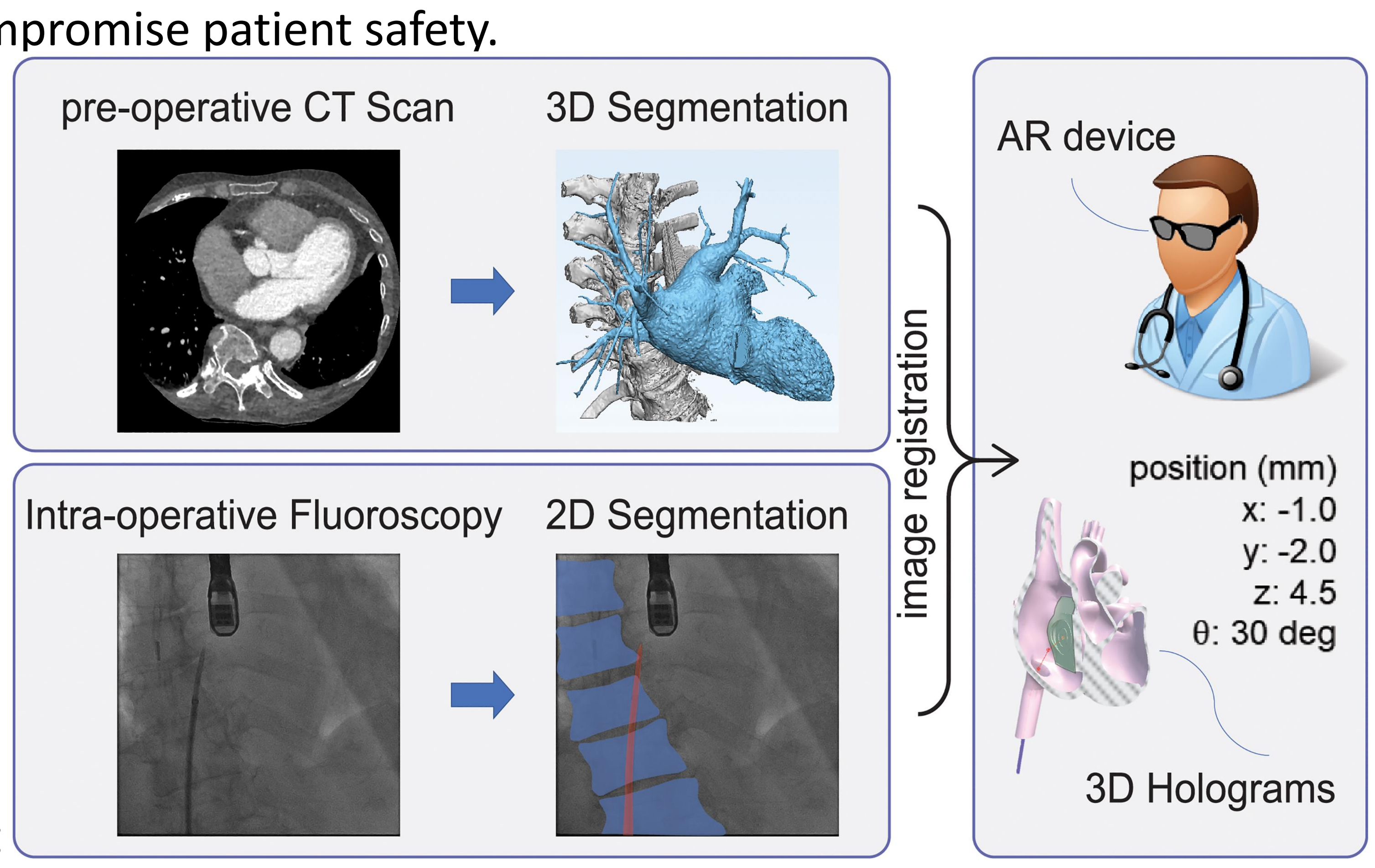

Figure 2. Overall procedure of the proposed AR assisted guidance system

During the procedure, typical mono-plane fluoroscopy will be utilized to provide guidance, (as is standard practice), however, when the physician has the delivery sheath within the target structure, bi-plane fluoroscopy images will be acquired to allow for validation of the mono-plane Z-coordinate prediction. If the fluoroscopy results and the imaging system hologram both indicate that the delivery catheter is in the correct position, we can be confident in the accuracy of the system. A post-study questionnaire will then assess each physician's experience with the added bio monitors and whether they felt that the instruments interfered with the normal operational flow.

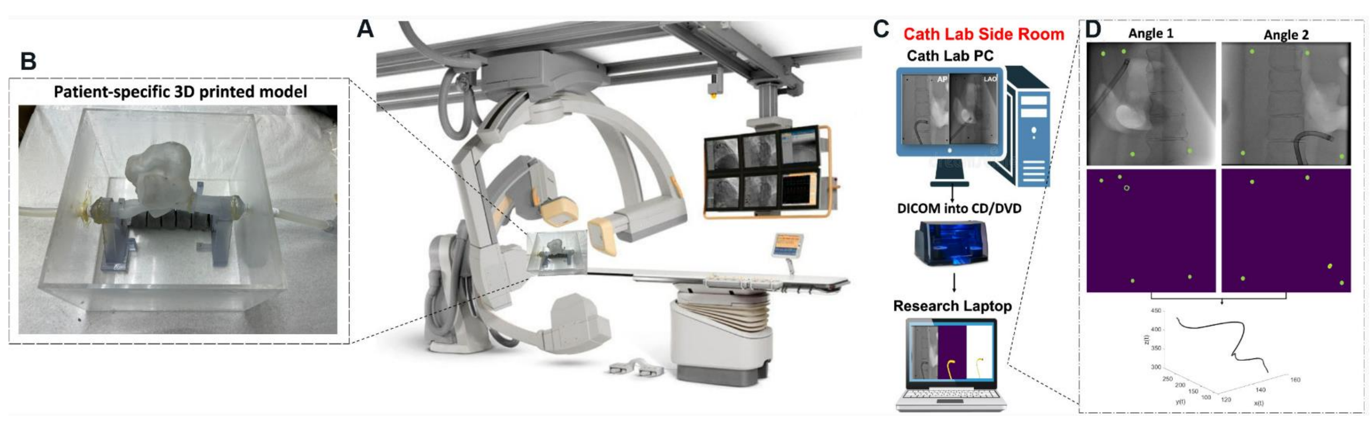

Figure 3. (A) Image of the 3D printed heart (B.) on a c-arm. (C) Scheme of the image transfer process of the post processed catheter tracking. (D) Image processing and deep learning steps of the fluoroscopy images.

Conclusion & Next Steps

The findings of this study will allow us to observe the utility of the imaging program and allow for its widespread implementation to improve the accuracy and safety of future operations. This project has the potential to not only benefit future cardiac procedures but also shows promise to be incorporated into education curricula across training programs and fields of expertise with the goal of allowing it to be expanded to cover a diverse array of catheter-based operations.

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References:

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