Toward Steerable Needles Autonomous Motion for Mitral Valve Repair

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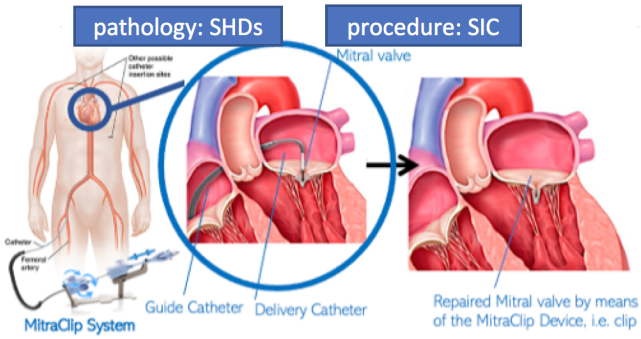

Fig. 1. Mitral Valve Repair with MitraClip System^{TM} for SHDs: overview of SIC procedure.

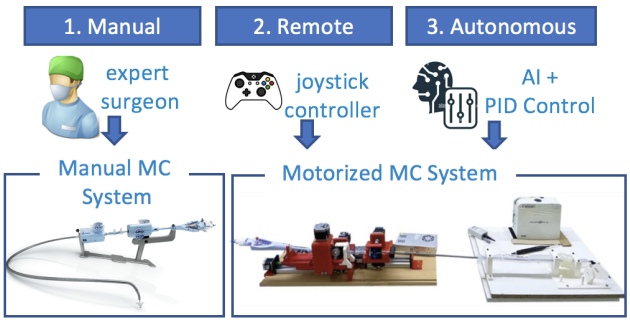

Fig. 2. (1) manual actuated approach on the sensorized MC system, (2) remotely actuated approach on the motorized MC system, (3) autonomous approach on the motorized MC system.

I. INTRODUCTION

SIC procedures allow for the treatment of SHDs (Fig.1), i.e. disorders characterized by anomalies in the heart valves, heart wall, and heart muscle structure, by transcatheter implantation of repair or replacement devices. Initially designed to treat patients who were ineligible for open-chest surgery, SIC treatments are becoming increasingly popular as first-line treatment due to lower trauma, shorter hospitalization time, and equivalent efficacy to open chest surgery for SHDs [1]. On the other hand, SIC procedures are not ergonomic and are technically demanding, since the operator must maneuver the proximal end of the catheter to define the motion of the distal end in the unconstrained and dynamic intracardiac environment. Furthermore, a steep learning curve and the procedural success related to the operator's experience and ability to characterize the SIC procedures. Robots can improve the percutaneous procedures' efficacy and accuracy, by performing automatic, repetitive and standardized task.

II. OBJECTIVES

Specifically, the aim of this work is to design and propose a robotic support platform for the commercially-available MitraClip^{TM} (MC) system®, in the context of Artery European project [2], through the use of a steerable and controllable robotic catheter system.

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III. METHODS

This work, thus, develops (1) a sensorized manual platform for initial expert movement acquisition, for transfer learning and as a surgeon training platform and (2) an electromechanical support with autonomous control to automatize the intra-cardiac phase of the mitral valve repair percutaneous surgical procedure. As depicted in Fig.2 the first approach is actuated by an expert user, the second approach is remotely actuated by a joystick controller, while the last one is base on the automatic definition of a path through an Artificial Intelligence (AI)-based method and Proportional Integral Deriverative (PID) approach to control the motorized MC system.

IV. RESULTS

Results for the 3 approaches are reported in terms of Time, Target Position Error (TPE) along each axes to test the accuracy and repeatability of the system. The Time and TPE, for the autonomous approach are respectively 15 sec; 0.9 ± 0.54 mm in X-axis, 0.83 ± 0.55 mm in Y-axis and 1.45 ± 0.28 mm in Z-axis.

V. CONCLUSIONS

Although the use of manual devices in SIC is currently successfully applied in the clinic, the aim of this study is to demonstrate that the proposed robotic approach could produce the same, or even better, accuracy and repeatability.

REFERENCES

[1] Peter Lanzer. Textbook of catheter based cardiovascular interventions. Cham: Springer International Publishing, 2018.

[2] Robotics and AI to revolutionize interventional cardiology, 2021.