MECHANISM DESIGN OF A PATIENT-MOUNTED MRI COMPATIBLE ROBOT (MCROBOT)

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INTRODUCTION

Advantages of using MRI compatible robots are now apparent to everyone. Although the rate of designing these robots and doing research in the field is increasing [1], still designed and manufactured samples suffer vastly from difficulties such as accuracy, weight, cost, dexterity, manipulability and versatility[3].

MCRobot illustrated in figure 1, is an MRI compatible mechanism which is designed for the purpose of assisting surgeon in intraoperative operations. Being equipped with axisymmetric tools like needle, probe, catheter, stylus, syringe, tube and cannula, it is able to partake in variety of operations such as placement, injection and aspiration.
The novelty of our design is in that MCRobot is a patient-mounted robot being actuated by tensile cables while similar mechanisms are mostly table-mounted having piezoelectric or hydro/pneumatic actuators.

METHOD

Any arbitrary frame in 3D space could be described by 6 degrees of freedom. However since our robot's end-effector is an axisymmetric needle, clearly whole system's degrees of freedom could be decreased to 5.

Obviously in designing a robot, each of these degrees of freedom should be employed to facilitate a special aim. In our case, theses aims fall into 3 different categories; putting the needle's tip toward the skin surface, orientation of needle and Insertion and handling of needle or special tool. Since MCRobot is a patient-mounted manipulator, automatically the former category would be omitted, bearing in the mind that following this concept, there remains no need to approach the needle tip toward the skin surface. Finally if we take the last necessary linear motion which is shooting the core part for biopsies or seed ejecting for brachythrapies into account, our mechanism would be a 4 degree of freedom robot. Assuming more degrees of freedom for mechanism would cause to have higher costs, less accuracy and more complex control system. The DH parameters of MCRobot are shown in table 1.

In order to evaluate the efficiency of our design, structural length index is estimated. Q_L is defined as the ratio of the manipulator length sum to the cube root of the workspace volume to get a quantitative handle on relation between amount of material and volume of work space $Q_L = L/\sqrt[3]{w}$. Where L (the length sum of manipulator) is a rough measure of the length of the complete linkage, given as $L = \sum_{i=1}^{N}(a_{i-1} + d_i)$.That a_{i-1}(link length) and d_i(the maximum offset for prismatic joints) are constants of DH parameter and w is the volume of the manipulator's workspace. Thus a better design has lowerQ_L.[2]

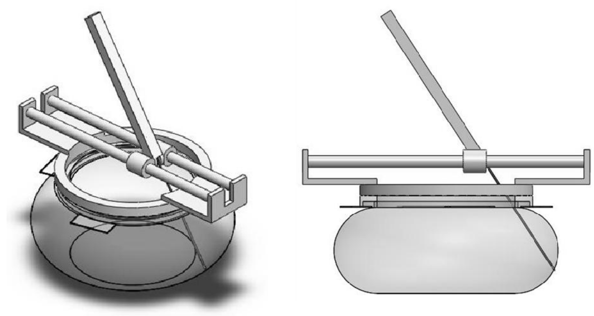

Figure 1: MCRobot

DISCUSSION

For our design, structural length index (Q_L) is estimated to be 2.91. This assures high efficiency and existence of creativity in designing MCRobot.

CONCLUSION

The following items are observed to be the advantages of implementing patient-mounted concept in designing MCRobot; Small size/footprint (minimal obstruction), Close proximity to surgical site, No patient/anatomy immobilization, No tracking/real-time repositioning, Small workspace, fine positioning device, Potentially higher accuracy, Intrinsic safety due to small size/low power. On the other hand, manual course positioning is considered as its disadvantage

REFERENCES

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i	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	0	θ_1
2	±90	h	r_1	0
3	±90	0	0	θ_2
4	±90	0	l_1	0

Table 1: Denavit-Hartenberg parameter