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DESIGN OF AN INSTRUMENT GUIDE FOR MRI-GUIDED PERCUTANEOUS INTERVENTIONS

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Abstract
This paper describes the design of an instrument guidance device for percutaneous interventions in closed bore magnetic resonance (MR) imaging systems. The device consists of a curved arm piece that travels around a circular base, and an additional needle holder that travels along the curved arm – thus providing two angular degrees of freedom that enable an ablation probe to pivot about a remote center of motion located at the skin entry point. The device is intended to be mounted onto a custom built MR coil that rests on the patient while they are imaged. Exact constraint design principles were used to incorporate translational bearings into the plastic parts. Thumbscrews were used for preload and locking so that the probe guide could be fixed along a specific trajectory. The device was prototyped via stereolithography as a proof of concept and demonstrated that a probe could be angled about a remote pivot point.

1 Introduction
Magnetic Resonance Imaging (MRI) offers good soft tissue contrast without harmful X-rays, making it an ideal imaging modality for many applications, including minimally invasive percutaneous procedures such as biopsies and ablations. For these procedures, a thin instrument (often multiple) are inserted through a single puncture in the skin to a lesion under the guidance of the MR images. These procedures often require large amounts of scanning time to accurately position the instrument to reach its desired target location. After scanning the patient to determine an entry point, the interventionist makes an initial insertion to a depth such that there will be clearance between the probe handle and the imaging bore. Then the patient is rescanned to evaluate if the probe is along the desired trajectory. The patient is then brought back out of the imaging bore to readjust the probe if necessary before inserting it a little deeper into the body. This procedure of scanning, removing the patient from the bore, readjusting and inserting the needle, and sending the patient back into the bore is often repeated several times until the target is reached and the intervention itself can proceed. An additional challenge with more powerful MRI machines is that they are closed bore, limiting the access of the interventionist to the patient.

Cryoablation, which kills tissue with extreme cold, is one intervention that is used in conjunction with MRI to treat solid tumors. Each 17 gauge cryoablation probe produces an ice ball at the tip of the probe to destroy tissue. In order to effectively treat an entire lesion, often multiple probes are placed. Accurate placement of the probes is critical to ensure complete tumor destruction and avoid damage to important anatomy in its vicinity. At the beginning of the procedure, the radiologist decides on the optimal probe location but inaccurate placement of one probe often results in the initial plan having to be modified.

Current Needle Guide Devices
Over the past few decades there have been a number of devices developed to aid needle positioning during image-guided interventions. One such telerobotic device for computed tomography (CT) guided procedures was developed at MIT [1]. The device was designed to be mounted to the patient to account for respiratory motion, and has four degrees of freedom: two angles for orientation, one needle insertion/retraction, and one to grip and release the needle. A spherical mechanism consisting of two crossed, nested pivoting hoops provides needle angulation and an additional carriage that moved with both hoops contains the mechanism for needle gripping and insertion. Each of the four degrees of freedom is driven by a small micromotor and planetary gearhead – thus limiting the device to CT and ultrasound guided interventions. This system is the most compact robotic needle guide proposed

to date but like many other systems that have been developed can only position a single needle or probe.

Other robotic systems have been developed with MR-compatible actuators so that they can be used in conjunction with MR-guidance. Pneumatic systems use compressed air to effect motion and are completely MRI compatible, even in the region of imaging interest. However, accurate position control with pneumatic actuators is generally difficult, and systems tend to be large and require a compressed air source. Hydraulic actuators, which use an incompressible fluid, are more rigid than pneumatics, but are slow and have a chance of fluid leaks that is unacceptable in a sterile environment. Piezoelectric motors can also be used in MRI compatible systems, including high frequency ultrasonic motors. These are nonmagnetic and thus are MRI safe, but use of electric current may cause electromagnetic interference (EMI) and distort the image. The Light Puncture Robot (LPR) developed in Grenoble provides positioning and insertion of the needle that is fully compatible with both CT and MR systems [2]. The needle holder portion of this robot has three degrees of freedom to orient and insert the needle, actuated by pneumatically actuated pistons and sprocket wheels. The device is strapped over the patient body with a support frame, with another two degrees of freedom available to position the entry point of the needle by adjusting the straps.

Innomotion from Innomedic is another system compatible with both CT and MR imaging [3]. It is attached to top of the scanner bore, with an arm that has five degrees of freedom, driven by pneumatic linear cylinders and controlled by a master haptic device. Pneumatically driven needle insertion has been planned but not implemented in the current model; instead the insertion must be done manually outside the bore. The first prototype was made with piezoelectric motors, but this design was discarded due to increased noise during the MRI scanning process, and the risk of inductive heating from the electric lines.

Hata et. al developed a needle guide, in which the surgeon changes the angles of the needle which are read by encoders, and an active linear XY movement guides the needle to the right position so the needle is still pointed to the target point [4]. The system is mounted to the bed of the scanner, and driven by ultrasonic motors. Another system by Larson et al. developed for breast biopsies uses ultrasonic motors driving telescoping rods to achieve actuation near the breast while keeping the motors away from the image [5]. This principle has been extended to a more general seven DOF robot that is attached to a gantry so the robotic arm may be positioned above the patient and manipulated with a haptic driver [6].

As well as robotic solutions, there have also been a number of passive needle guides that have been developed to assist with image-guided interventions. Civco Medical Solutions manufactures a line of passive assistive devices to aid the interventionist including the Civco CT Multi-Angle Instrument Guide [7]. This device provides feedback of instrument angle via bubble levels. It includes a quick release mechanism to allow for a disposable needle guide portion to be easily released from the alignment mechanism. The device is intended to attach to Civco's Positioning Arms which are attached to the CT or MR gantry

The NeoRad Simplify Needle Holder [8] is composed of needle-holding clips which can be clipped onto an arched support at an angle, and the arch itself can be folded, for two degrees of angular freedom. Multiple clips with needles can also be attached and detached. The Radi SeeStar Needle Guide [9] uses two concentric hoops similar to [1] to position and guide the needle holder over a semi-hemispherical surface, with the guide always pointed at one entry point. A screw mechanism clamps the two concentric hoops together to resist motion and form a stable platform for the guide. However, there are no visual markings to easily record the angular position of the hoops.

Contributions

This paper documents the process of designing a passive device which when interfaced with imaging software, will enable precise and accurate positioning for percutaneous instrument insertion in MRI-guided interventions. The device is initially designed for cryoablation interventions where multiple probes must be placed, but is also intended to be suitable for a broader set of interventions.

2 Design Development

Functional Requirements

Considering the challenges of clinicians and the needs in performing MR-guided cryoablation interventions in a closed-bore magnet, the selected functional requirements of the device are:

1. Accommodate coil – One challenge unique to MRI procedures is the necessity of affixing a flexible MRI coil on the patient over the region of imaging interest, as seen in Figure 1. The flex coil creates an additional constraint for the radiologist, as probes must either go through the holes of the coil or enter the body at an angle from outside the area of the coil. Any strategy for improving current procedures must work in conjunction with where the coil is placed.
2. Register and calculate correct trajectory – The mechanical device must be able to be integrated into a system that can register its location with respect to the imaging coordinate system.
3. Guide probes to correct trajectory – Knowing the correct trajectory, the device must have a way to position the probe in the correct location with the appropriate degrees of freedom. MR coils can be attached to any side of the patient, and current insertion paths generally fall within the ±45˚ range from normal to the skin, with an extreme to 80˚ from vertical. The device should accommodate these angulations.
4. Precision and reliability – The device must find the same trajectory repeatedly. Sensing may be incorporated to ensure accuracy. The device must also be stiff enough to maintain

the probe along the correct insertion trajectory in the presence of forces during the insertion process.

5. Accommodate multiple probes – Cryoablation interventions are normally performed with two to ten probes per procedure, so the device must be able to accommodate this. Most procedures use three 17-gauge probes.
6. Allow the probe to reach target – The average lesion is approximately 12.5 cm deep beneath the skin. The device must not interfere or hold the probes in such a fashion that does not allow them to reach the desired depth. Current probes are 17 cm in length. Thus the device should not hold the probe more than 4 cm above the skin surface.
7. Release probe after insertion – After the probe reaches the desired target, the device must release the probe so that the probe has the freedom to move with the patient to decrease the risk of injury. The required angular range of motion is approximately ±12.5˚.
8. MRI Compatible – To be usable in an MR environment, devices must 1) be MRI-safe, which means they must not be moved or attracted by the magnets, 2) not interfere with the image quality of the scan, and 3) operate as designed in the MRI environment [10]. Non-metals as well as aluminum, some stainless steels, and beryllium copper have been shown to be MRI compatible.
9. Sterilizable – Everything in the MRI environment must be sterilized prior to the procedure, so the device must have no recessed features that make sterilizing difficult. Else, the device should be designed for one time use.

Figure 1: A coil placed over a patient in the scanner bed[11].

Strategy Selection

Based on the above functional requirements, four different strategies were discussed as shown in Figure 2. These strategies incorporated different choices regarding 1) mounting of the device, 2) actuation method, 3) number of entry points for probes, 4) multiple versus single guides, and 5) registration method. Each strategy required mounting to a different surface:

1. The coil-mounted strategy is a device that is mounted over a window in the coil. The device directs probes to a shared entry point with multiple probes that can travel around a circular base, and telescoping arms that travel in an arc such that the probes would all convene to one spot on the patient's skin, allowing for only one incision point to reduce risk of infection and reduce healing time.
2. In the body-mounted strategy, the mechanism includes long arms that reach over the edges of the coil to access the body through a window. The movement is controlled at some distance away from where the probes are inserted, so it would be easier to motorize. However, this type of cantilevered structure may be too heavy and thus difficult to securely mount on the patient.
3. The scanner bed mounted strategy would have a single robotic probe holder that places one probe at a time. An advantage of this strategy is that it would be mounted to a stable surface, but given the variability in size of patients, there could easily be not enough space on the bed. Placing one probe at a time also gives flexibility to the positions and angles of insertions.
4. External mounted systems were also considered. A robot arm can place probes while remaining entirely outside the imaging bore. This would be relatively easy to actuate as no parts enter the bore. After a scan the patient would be removed from the scanner so that the robot can place a probe, and then patient would be rescanned. As such, this strategy requires the patient be brought in and out, using valuable time. Another disadvantage of this strategy is that its structure and actuators must be very stiff and thus would be expensive to achieve good positioning accuracy.

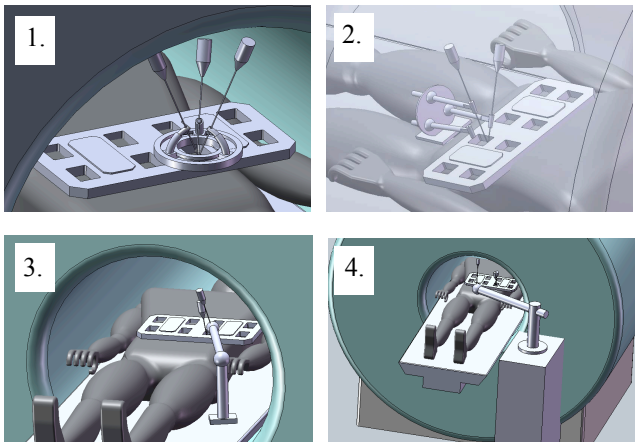

Figure 2: Strategies considered for instrument guidance mechanism.

Ultimately the coil-mounted strategy was selected. Table 1 presents a Pugh Chart with parameters that factored into the decision. The term intuitive describes how easy it would be for an interventionist to know how the device worked without explanation. Actuability describes the ease of attaching motors while maintaining full MRI compatibility. Novelty comes from a concern to develop a device that has not been made before. Weight is an important factor as it contributes to safety, ease of use, and cost. Risk refers to how likely a device designed is likely to be safe and meet specifications.

The selected strategy would direct probes to a shared entry point with multiple probes that can travel around a circular base, and telescoping arms that travel in an arc such that the probes would all convene to one spot on the patient's skin. This

strategy was deemed the most attractive for its simplicity, as well as the interventionist's intuitive feeling for how the device works, which is crucial for it to be adopted by clinicians. This type of coil-mounted strategy also had the possibility of developing into a novel integrated MRI coil device for interventionists. It is possible to imagine a custom coil used for registration, and this device could have features that allows for accurate positioning with the coil, such as via kinematic couplings [12].

Table 1: Pugh Chart of strategy selection

	Coil mount	Body mount	Gurney mount	External mount
Intuitive	+	-	0	0
Actuability	-	-	0	+
Novelty	++	0	0	-
Weight	+	-	--	-
Risk	0	-	-	+
Total	+3	-4	-3	0

Concept Selection

After deciding on the strategy, four concepts to achieve this strategy were developed as shown by hand sketches in Figure 3. We focus on the design of a passive device, with the intention of actuating the device in future work. The concepts all provide two angular degrees of freedom: rotation about the entry point normal to the patient's body surface (θ), and angulation that deviates from the normal axis (φ). It was decided to use a carriage system that rides over a support system as opposed to a telescoping system, as a carriage system provides more range of motion and is simpler to manufacture using plastic injection molding techniques. Changes in φ can be changed either through a hemispherical track (Figure 3b and 3d) or a horizontal track with a support at the entry point that constrains that point (Figure 3a and 3c). It is also possible to have individual arms that support different probes (Figure 3a and 3b), or to have a full support that traverses the span of the device and have individual carriages pass over (Figure 3c and 3d). The full bridge concepts would require the probe to be released from the mechanism before placing another probe. Furthermore, the order for placing probes must be calculated beforehand to avoid collisions between the instrument and probes priorly placed. Individual arms for each probe holder would take less time as the interventionist could insert multiple probes and hold the needles in position before inserting subsequent needles. This would require one arm to be longer than others, such that the needle could still reach the vertical position.

To aid in the selection of the best concept, the error associated with the deflection of each concept structure was considered along with the convenience for the interventionist. Based on analysis based on elastic and plastic theory and finite element analysis of first order models, the deflection at the tip of the probe was found given an applied load of 10 N to the probe holder. As expected, the curved beams were found to be stiffer than the straight beams and the bridge concepts were much stiffer than individual arms. In addition, we assumed that there would be bearing errors on the same order of magnitude as that of the structural deflection. For the spherical cases, there are two bearings, one along the base track and one along the support track, that will need to be constrained when locking the device in position to guide the probe and could contribute error. In the Cartesian concepts, the probe holder swings freely with an opening at the entry point that acts as a constraint for the angle. The opening has to be made wide to accommodate angulation, creating another error source. Thus there are three additional sources of error in the Cartesian system. These considerations led to choosing the "spherical arms" for the detailed design phase. The end-point targeting error associated with structural and bearing errors for this concept was predicted to be 0.6 mm from FEA and bearing considerations.

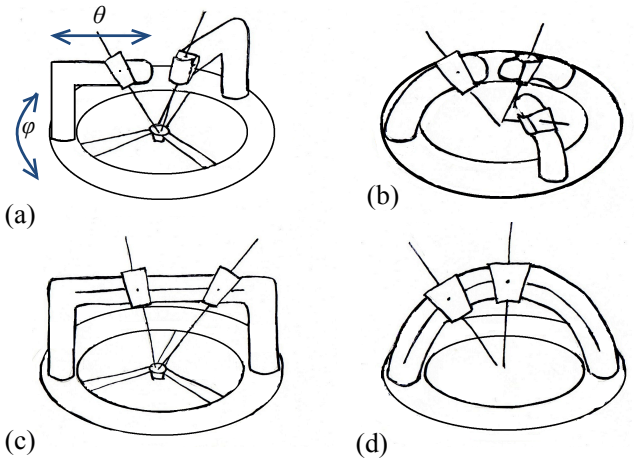

Figure 3: Hand sketches of the 4 concepts (a) Cartesian arm. (b) Spherical arm. (c) Cartesian bridge. (d) Spherical bridge.

3 Detailed Design

Design Overview

Figure 4 shows a solid model of the device illustrating its three main components: the base, the arm, and the probe guide/holder. The arm is made from two parts for manufacturing purposes, and is free to slide around the circular base. The probe guide rests on and slides along the curved arm. Both the arm and the probe guide can be locked in place with thumbscrews. These two degrees of freedom allow probes to be pivoted about a remote center of rotation a distance of 10 mm below the bottom of the base to account for the thickness of the coil. In the hypothetical workflow, after these two degrees of freedom are set, the probe is then inserted through the guide. After insertion of the probe, it can be released from the guide to reposition the arm for the insertion of another probe. The added advantage of this is that once a probe is inserted, it is free to move slightly, reducing the risk of injury to internal tissues. Two concepts for the probe gripping and releasing mechanism were explored and prototyped.

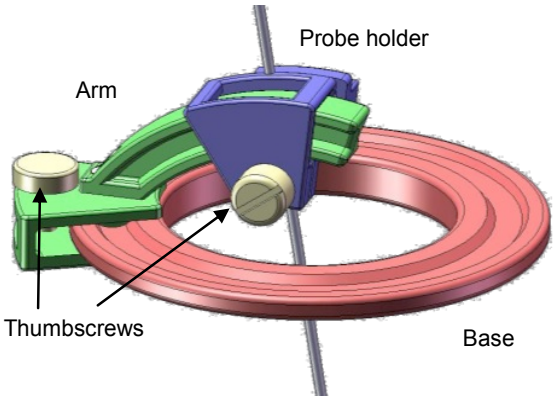

Figure 4: Solid model of device. Two tracks allow for orientation of the needle in two angles.

Structural Design

Many geometric arrangements were considered when designing the device structure. The proposed device is unique from other devices in that it will sit on a plane above the skin and insertion point due to being mounted on the coil. The design was started by considering a curved beam that had a central radius of 35 mm, to make sure that the needle holder would not take up more than 4 cm of length of the probe. However, because of the thickness of the coil, the remote center of rotation for the needle had to be 10 mm below the base of the device. This was to ensure that the probes would pivot about the skin entry point, thus minimizing tearing of tissue. This is shown below in Figure 5. This results in a limited range of angulation. A larger overall structure could be employed but with the trade-off of reducing the maximum depth to which the 17 cm probes could be placed. Another consideration was that the needle guide would have to be positioned on the side of the arm. This is required so that the probe guide is always in line with the center of the circle and rotation occurs about the entry point (Figure 5b).

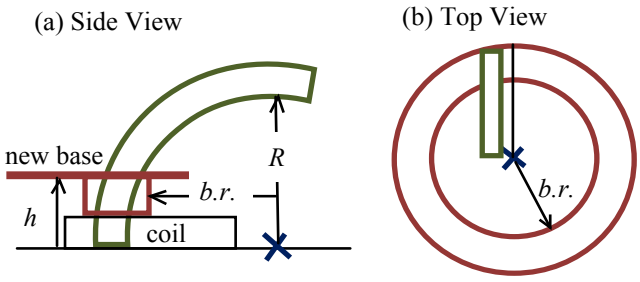

Figure 5: Diagrams of offset of (a) the base and (b) the arm.

The device's geometric parameters are shown in Figure 5; the radius of curvature *R* is 30 mm; offset from coil *h* is 18 mm and the base radius *b.r.* is 24 mm. The probe was designed to be directed at the entry point at the center of the circular base, and the probe guide was designed to be on the side of the arm so the arm is also offset 2 mm from the midline of the circle. This creates the potential for torsional loads on the arm and this was taken into account when sizing its width.

Bearing Design

The device is required to be precise and repeatable while being inexpensive to produce. The approach taken to meet this functional requirement was to use the principle of exact constraint design to incorporate features into the plastic parts for the bearings – thus minimizing the number of components. Each rigid body has 6 degrees of freedom and for each of the two angular degrees of freedom a single translational degree of freedom that is selectably lockable was required. Thus the bearing for each sliding part contained 2 translational constraints and 3 rotational constraints. Friction from a lock or screw would provide the 6th constraint. Thus, there must be 5 constraints total, such as shown in Figure 6. For this V groove design, the 4 contact points in the V constrain rotation about the x and z axis, as well as translation along the x and z directions. Adding an additional constraint away from the center of those constraints will support the load and keep it from rotating about the y axis, and keep the 4 constraints above from lifting off should the force be applied opposite from pictured.

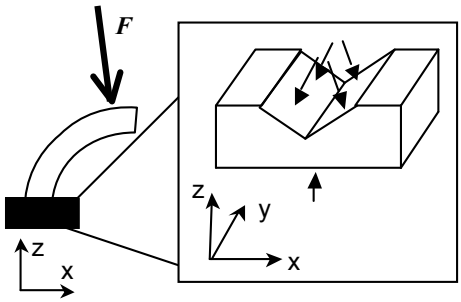

Figure 6: Force acting on the arm and kinematic constraint that could support this load.

To make these point contact constraints, spherical surfaces on flat surfaces were used. The spheres create tangent point contacts with the flat, and were designed to be the only contacts between moving pieces. The device was designed to have a clearance of at least 0.3 mm between surfaces where there is to be no contact. Cross sections of the models can be seen in Figure 7. The bearing for the base is designed to snap on and the bearing for the needle holder can be slid over the arm.

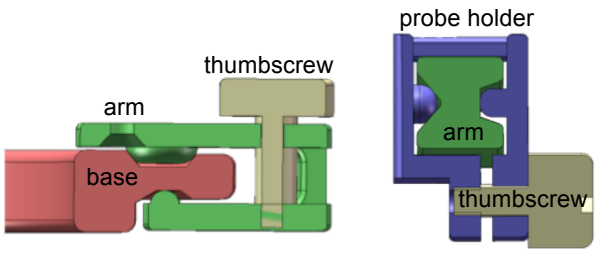

Figure 7: Cross sectional views of the bearing designs used in the arm base and the probe holder carriage.

Thumbscrews were chosen to properly preload the bearings, and provide a means for locking them in place. These are simple, intuitive to use, and require just one extra part. Saint-Venant's principle was considered when sizing the spacing between the bearing contact points. To ensure accuracy, the bearing support length *d* must be greater than 1/3 of the length from the bearing to action arm *l* as illustrated below in Figure 8.

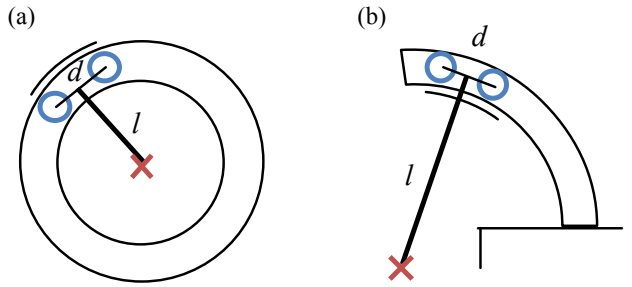

Figure 8: Saint-Venant's Principle: *l* must be less than three times *d*. (a) Schematic of the top view. (b) schematic of side view.

In the top view, l = 29 mm, and d = 10 mm to satisfy Saint-Venant's Principle. From the side view, l = 34 mm, and d = 11 mm, which almost satisfies Saint-Venant's Principle. A larger d was not convenient because the carriage would be bigger and take up room on the arm, limiting the range of motion.

Finite element analysis (FEA) was performed to ensure that preloading via the thumbscrews does not exceed the maximum allowable stress for plastic. FEA was also used to confirm that the arm base would not break in the process of snapping the piece onto the base. Figure 9 shows the stress distribution in the arm carriage, loaded for snapping onto the base. Safety factors of at least 2 were found for each piece.

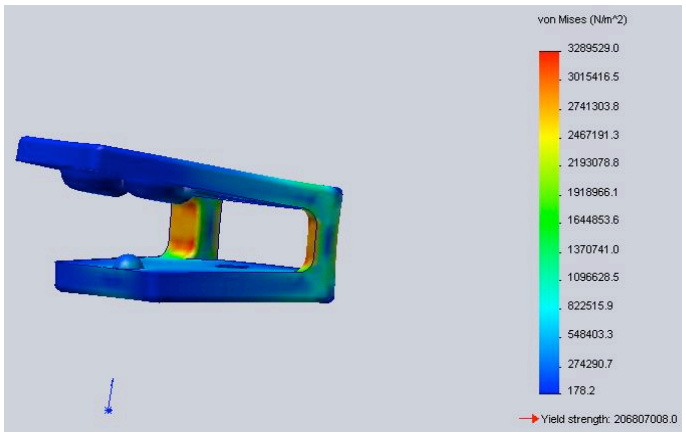

Figure 9: Stress distribution in the carriage of the arm for a displacement sufficient for it to snap on to the base. The maximum stress was 32 MPa.

Release Mechanism Design

The release mechanism enables the guide to be repositioned so a subsequent probe can be placed and allows each probe to move freely after insertion. Another functional requirement was that the mechanism must not fully detach to minimize the risk of losing or misplacing an extra part.

A number of different release mechanisms were considered such as those based on cam locks and screw locks. However, as the parts are to be made out of plastic, the compliance of the plastic was used as a spring in order to hold pieces together. Two concepts were designed as presented in Figure 10. One concept has a hinge and latch much like many plastic snap pieces (a), and another with just a cover to act as a retaining spring (b). While concept (a) has more pieces to manufacture, it may offer more freedom in releasing the probe. Concept (b) is simpler in design, but the holder can only be moved in one direction to release the probe.

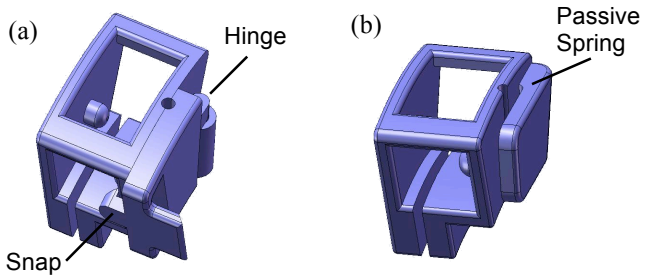

Figure 10: Two different methods of needle release mechanisms that were developed. (a) The snap concept. (b) The compliant spring version.

Design for Manufacturing

All of the plastic parts were designed for mass production through injection molding, preferably via a single pull. Windows were put in the back of the bearings to allow for a single pull to make the features. The whole arm piece could not be made in a single pull, thus, the arm was split into two pieces with two 2-56 plastic screws connecting them. The screws are reversely oriented in consideration of access to holes. Each of the two parts could be injection molded with a single pull, although each piece now has holes that must be drilled and tapped in a separate manufacturing operation. The assembly of the arm part is seen in Figure 11.

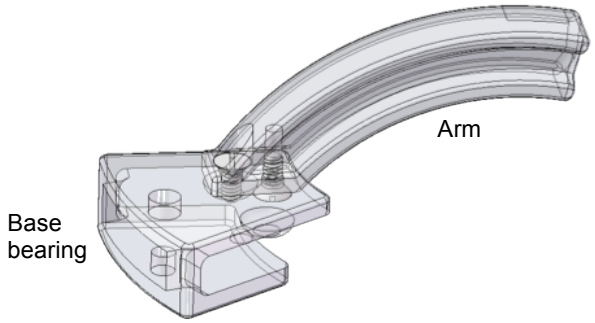

Figure 11: The arm part after considerations for manufacturing were made consisting of 2 pieces and screws.

Parts were also designed with similar feature thicknesses to ensure equal cooling time throughout the piece after injection

molding. As the model is seen in Figure 10, the probe holder carriage could not be injection molded via a 2 mold system. Additional windows could be added to the bottom side of the carriage to allow access to form the spherical features, or more advanced injection molding techniques could be used.

4 Prototyping and Evaluation

The device was prototyped using stereolithography of an ABS-like resin by Vaupell Rapid Solutions. Plastic screws were used to assemble the pieces together and provide correct preload. A final assembly is seen in Figure 12.

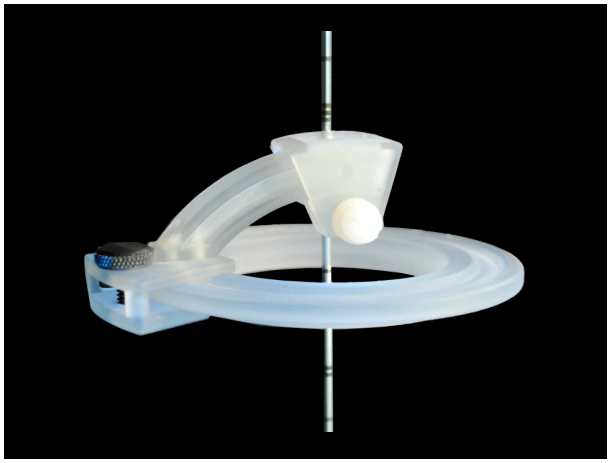

Figure 12: Photograph of prototyped instrument guide.

When the parts first arrived, the appropriate holes had to be tapped, and the tracks needed sanding due to overbuild in the stereolithography process before the carriages could move smoothly along the tracks.

Tightening the thumb screws held the carriages stationary along the tracks even when pushed. After tightening, the probe holder carriage seemed to be stiff with no discernable movement in the pieces when trying to wiggle the carriage by hand. The carriage of the arm piece was less secure. Lifting up on the tip of the arm did cause the bearings to disengage slightly, however this type of loading is not expected to occur during a procedure. After snapping on and off the arm carriage a few times, there was considerable play in that bearing due to the wear of the plastic. The arm carriage was subject to additional wear as the spherical nubs rubbed against the thick lip of the base when the assembly was forced on and off. Eventually, this wear along with the sanding created loss of contact between the four contact points and the V groove, allowing for considerable waggle of the carriage as rotation about the vertical axis is no longer fully constrained. Despite this wear, the preload was able to hold a force of pushing down on the arm with 2 fingers.

Another premise of this device is that it has the ability to position multiple needles. Given the dimensions needed to ensure stability and accuracy, multiple arms and probe guides could not be mounted on the same base. There is however an ability for the holder to hold more than one probe on a single arm, as shown in Figure 13. However, the envisioned use for this device is that after a probe is placed, it would be released from the needle guide and the arm and carriage would be positioned to the location for the next probe.

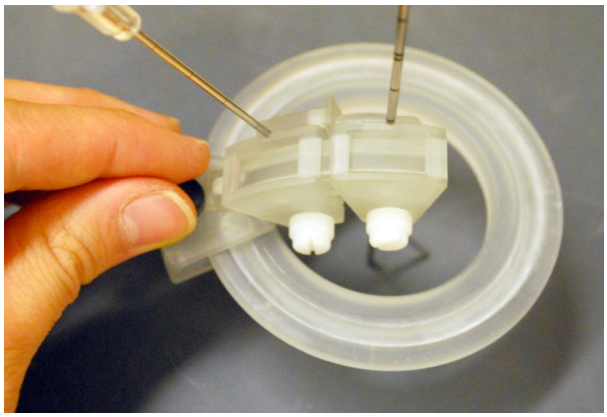

Figure 13: Device with 2 probe holders on the arm.

The maximum angle of the device from vertical was measured to be approximately 35˚, which is 10˚ off from the targeted specification. It is also confirmed that the device does direct probes to one remote center of rotation below the base of the device. Another observation of the device is that it is very small, and is operable by nimble hands. Some features such as the thumbscrews could be made bigger to be more ergonomic, or switched to a different clamping mechanism. It is also possible that such a small device may be able to be mounted onto the patient directly, but then it would be harder to fulfill the ideal of having it integrated with a MRI coil for registration.

Both needle holding mechanisms were prototyped, and both concepts were able to firmly hold a needle in position. In the snap concept, the pin had to be sanded down in order to fit in the hole. The snap shut easily, and was very snug and held the needle in a position. The one-piece spring cover also held the needle in the position, but in the prototyped version the spring cover was too stiff to easily insert the probe directly, and there was no good way to release the probe. More optimization and testing should be done to find the correct compliance that would allow the cover to be easily opened. For the one piece concept, the probe holder carriage itself will have to be loosened before the grip on the needle can be released, whereas for the concept with a separate snap piece, it can be released without moving the entire carriage.

5 Conclusions and Future Work

The prototyped device is a proof of concept to the feasibility of an instrument guide for MRI guided interventions. The device worked for the most part as designed, and can be used to define two angles and hold multiple probes directed at the entry point. There are many next steps to be taken in order for this device to transfer into a successful probe guidance device.

First on the prototype manufacturing, a more wear resistant material than from a rapid prototyping 3D printer should be

used. In addition, the exact tolerance of the bearings should be found to ensure that the bearings have a long life and remain kinematically active and so that sanding is not required. Further testing may be done to see how much the structural design could be optimized so arms and carriages can take up less space so there could be potentially more probe holders and a better resolution for how far apart the probes must go. Analysis and testing to find the proper preload that would allow for the carriage to be held in proper position should be conducted. Labels that mark the two angles also need to be added in order to tell what angles the probes are entering at. While the thumbscrews enabled the bearings to be preloaded and the needle holding mechanism functioned accordingly, a more ergonomic design is beneficial to improve the usability of the system.

Aside from the mechanical device, the system should be incorporated with some imaging based software similar to [13] to track the location. Since the original intention was to mount the device on a customized coil, the coupling system needs to be designed. Kinematic couplings provide excellent accuracy [12] and should be used for attachment of the device base to the surface of a custom interventional MR coil. Given the small size of the device, either the coil can be designed to have very small openings for these to go over, or the device itself could have wings that can expand over to the coil. The mounting method should not hinder the rotation of the arm around the base of this device. It is imagined that there are special features on the coil to aid in registration as well as coupling with this device. Possibilities for actuating this device can also be developed in the future.

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