Mouse Positioning Device for Longitudinal Cancer Research

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Abstract

Researchers at the University of Wisconsin-Madison Carbone Cancer Center utilize animal models in their studies. The Small Animals Imaging Lab at the Wisconsin Institutes for Medical Research provides state-of-the-art, noninvasive imaging techniques to the UW cancer center to monitor the development of cancerous growths in mouse models [7]. The imaging lab uses a Siemens Inveon micro PET/CT scanner, which combines Positron Emission Tomography and Computerized Tomography to identify the locations of cancerous growths within the body. During scans, mice must be secured to the scanner bed with their limbs restrained and their noses secured in the nose-cone, which delivers isofluorane gas to the animals. Lab personnel currently restrain mice by taping them to a rectangular cardboard bed, which is then taped to the carbon fiber scanner bed (Figures 1 and 2). The Small Animals Imaging Lab would like a more precise, hassle-free device for restraining mice during scans that would allow personnel to accurately reposition mice for serial scans [2].

Figure 1: Mouse Taped to Current Cardboard Bed

Figure 2: Carbon Fiber Scanner Bed

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Introduction

Reasons for a New Device

The Small Animals Imaging Lab located in the Wisconsin Institutes for Medical Research (WIMR) needs a solid, adjustable device to restrain mice during Positron Emission Tomography and Computerized Tomography (PET/CT) scans. These scans are used in cancer research to pinpoint and monitor cancerous growths within the animal. The device must restrain the animal’s extremities to prevent movement and must include a quantitative analysis device to replicate the animal's exact anatomical position. The device should improve efficiency for animal restraint compared to the current cardboard restraint device.

Evaluating New Cancer Treatments

The Small Animals Imaging Lab at WIMR is a very prestigious institution that provides high quality PET/CT images to major imaging companies, UW cancer research facilities, and imaging development research [7]. Jamey Weichert, PhD is currently working with mice used in cancer research for the UW cancer center. Lab directors and graduate students depend on a mouse restraint device to ensure the quality of these images and to ensure that time will not be wasted aligning images from serial scans. Unfortunately, the current method for restraining mice during scans does neither. Lab personnel are looking for a device that will effectively restrain the animal subject during a scan, will not interfere significantly with the imaging, and can be used to effectively reposition a mouse for serial scans over a two to three week period [2]. By designing a more effective mouse restraint, our group can help ensure the integrity of scans and help reduce the amount of time wasted restraining mice and aligning images.

Devices Used by Other Labs

Though many devices currently exist for restraining mice during PET/CT scans, these devices tend to be complicated and expensive. For instance, Numira produces a ‘multimodality imaging scanner’ designed to ensure precise repositioning for serial scans (Figure 3). This device uses a disposable foam bed to ensure accurate repositioning and provides easy attachment points for tubing during the scan. However, a mouse model of Numira's imaging chamber costs $1650, which is far outside what the lab is willing to spend on an animal imaging chamber [5].

In a study of the methodology of image registration for small animal multi-modality imaging, Patrick L. Chow, David B. Stout, Evangelia Komisopolou, and Arion F. Chatziioannou created a custom chamber for holding mice during scans (Figure 4). The device consists of a cylindrical Lucite chamber with removable 'alignment posts for the mouse's limbs'. Though the chamber will not attenuate considerably in PET/CT images, lab attendants must tie down each limb individually to ensure reproducible positioning [1].

In a third type of imaging chamber produced by m2m, mice are secured in an adjustable tube undetectable in PET/CT scans (Figure 5). This device includes a heating mat and is compatible with mounting platforms on the Inveon micro PET/CT scanner. However, this device is priced at $3100, far outside the budget of the lab [8].

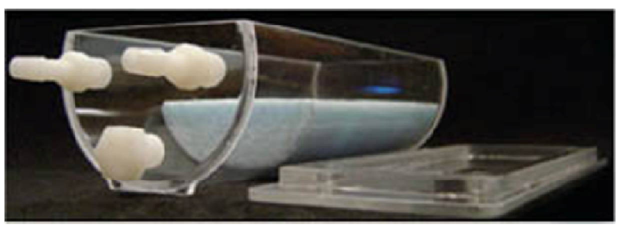

Figure 3: Mouse Imaging Chamber from Numira [5]

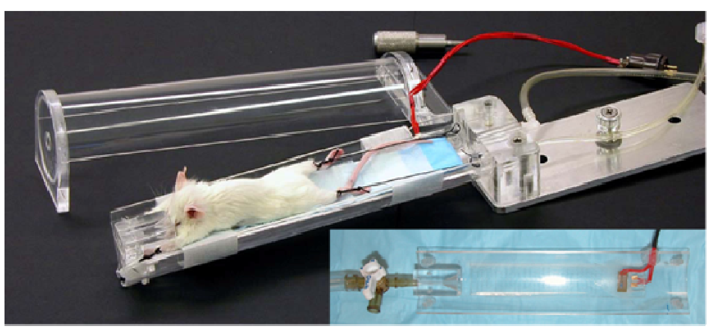

Figure 4: Custom Imaging Chamber [1]

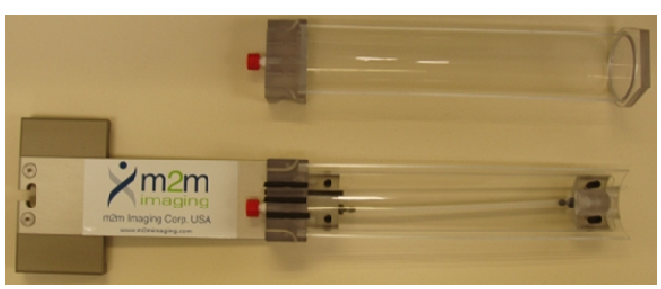

Figure 5: m2m Imaging Chamber [8]

Design Criteria

Our design must be compatible with the Siemens Inveon micro PET/CT scanner and equipment currently used by the client. In order to achieve this, our device must be 5 to 6" long, no more than 3.5'' wide, and no more than 0.5'' thick. The device must attach securely to the existing carbon fiber scanner bed and must not interfere with the nose cone attached to the bed. It must be able to accommodate mice ranging from 20-50 grams in weight. The device should be adjustable and include a method of measurement so lab personnel can replicate the exact anatomical position of the mouse for future scans. Over the course of the study, the position of the mouse should be within one millimeter of the original position of the animal. The device should be durable enough to withstand multiple scans of 3-10 mice over multiple two-week periods. The material used to make the device have a low attenuation so that it will not interfere with PET/CT imaging. Carbon fiber would be the preferred material because it is the same material that the scanner bed is made of. The device must restrain each of the mouse's extremities to prevent the animal from leaving the bed in the event that it wakes up during a scan and conform to the RARC and lab protocols for animal safety. It should take minimal effort and no more than 5-10 minutes to restrain the mouse. Since hygiene is important when dealing with animals, the device must be easy to clean between uses and cannot be made of cloth or absorbent material. The target cost for this product is $100 or less.

Overview of Design Alternatives

All of our design alternatives have two things in common: fabrication materials and how they are attached to the existing carbon fiber bed. The boards for all three designs will be fabricated from the thermoplastic acrylonitrile butadiene styrene (ABS). ABS was chosen because it had an acceptable density and the least amount of attenuation compared to other materials tested in the CT scanner. After determining LEGOS are made of ABS, it was decided that ABS would be the best material to use for our boards [3]. In order to allow for exact positioning of the device on the bed, two short pegs will be attached to the underside of the device where the mouse's head and tail will be positioned. One peg will be 0.5" from the tail side edge and the other will be 0.5" from the head side edge. Both will be placed 1.75" from both the left and right edges. These pegs will be glued to the bottom of the device and will fit into two female fittings that have been glued to the scanner bed.

Sliding Velcro Slot Design

The sliding Velcro slot design incorporates an adjustable restraint into a simple board design (Figure 6). The board measures 5.5’’ long, 3.5’’ wide, and 0.125’’ in thick. Two 1.5’’ long slits separated by 0.25’’ will be cut in each of the four corners of the board. Pairs of slits will be separated 1.5’’ widthwise and 1’’ lengthwise. They will be 1’’ from the long edge of the board and 0.75’’ from the short edge of the board. A ruler with English System measurements will be etched on the outside edge of each pair of slits.

Prior to placing a mouse on the board, a 0.25’’ thin and 1’’ long double-sided strip of Velcro with the loops on one side and the hooks on the reverse side will be threaded through each pair of slits, making four Velcro strips in total. Additional Velcro strips will also be provided to replace dirty, misplaced, or worn strips. After the mouse is positioned, the Velcro strips will be tightened around the animal’s wrists and ankles until the mouse is secure. The Velcro strips will slide lengthwise along the body of the mouse to adjust for different sized mice. A ruler along the outside edge of the slits is used to record the exact location of each Velcro strip to ensure that the mouse will be accurately repositioned on the board for each successive scan.

Since the board is flat, the mouse’s body can be outlined with a wax crayon, EXPO marker, or permanent marker on the board to enable repositioning of the body in future scans. If the mouse’s body is traced, multiple devices would have to be fabricated for the lab because each mouse would need its own board. After the mouse is no longer a part of the study, however, the board can be reused. Since the lab does serial scans of 3-10 mice at a time, a maximum of ten boards would have to be fabricated.

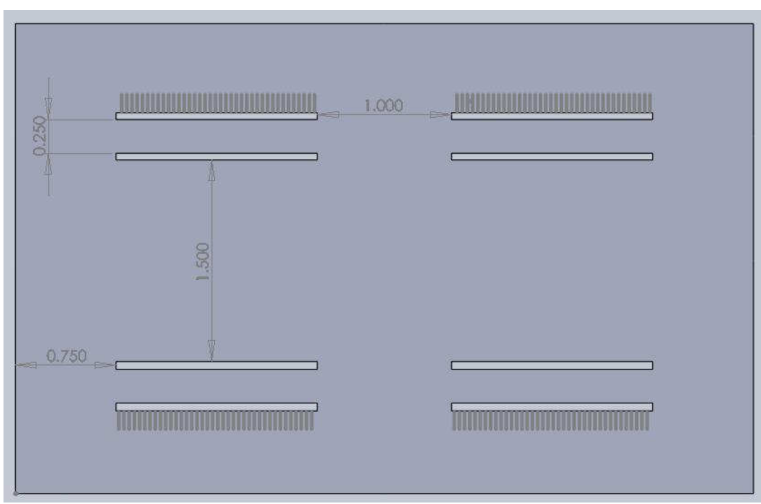

Figure 6: Velcro Slot Design

LEGO Board Design

The LEGO board design would use a LEGO board, fabricated by the LEGO group, with a length of 5.5”, a width of 3.5”, and a height of 0.125” (Figure 7). On the top of the board are right circular cylinders that extend 0.0625” above the board and have a diameter of 0.1875”. The cylinders are evenly spaced in rows and columns with 0.125” between each cylinder. The cylinders on the outer quarter inch of each side will be sanded down to allow a coordinate system of numbers and letters to be placed on the edge of the board. The remainder of the board will have 16 rows and 9 columns of cylinders for a total of 144 cylinders. The coordinate system will consist of the numbers 1-16 along the rows and the letters A-I along the columns.

The mice will be positioned on the device and LEGO pegs will be placed around the body to prevent it from shifting. The LEGO pegs would have female parts that fit tightly around the raised cylinders on the board. To restrain the mouse’s limbs, pegs made from two small LEGO pieces connected by rubber bands will be snapped in over the animal’s arms and legs. The bands connecting the small LEGO pieces will be made of a rubber material to prevent discomfort for the mouse and guarantee that the device can be cleaned if exposed to radioactive materials. After the pegs are snapped onto the cylinders, the coordinates of the pegs can be recorded so that the mouse’s position can be replicated in future scans.

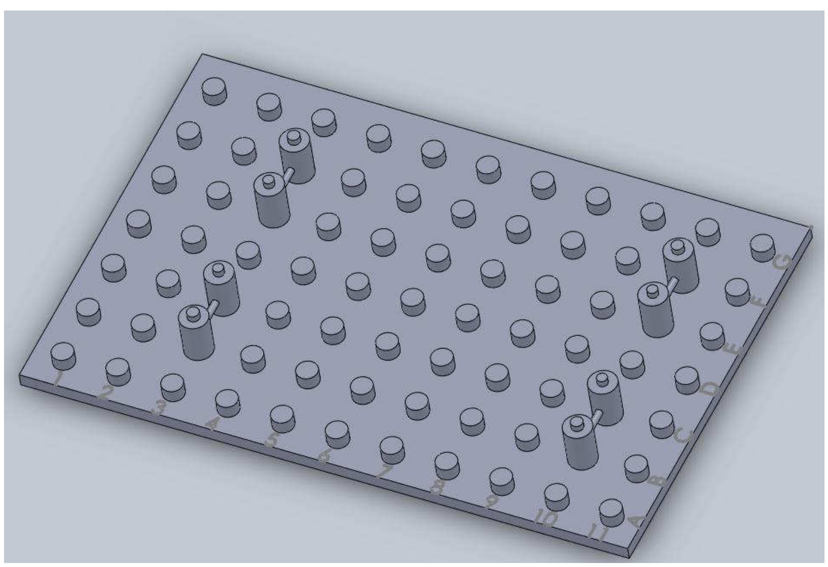

Figure 7: LEGO Board Design

Peg Board Design

The third design alternative follows the general idea of the LEGO design, but could be thought of as the inverse of that design (Figure 6). The device has a length of 5.4375”, a width of 3.5625”, and a height of 0.125”. 0.0625” holes will be drilled through the ABS sheet 0.125” apart. There will be an edge 0.25” wide surrounding the holes. This allows for 27 rows and 17 columns of holes for a total of 459 holes. Because there are so many holes, a coordinate system will be added to the tail side edge and the left edge. Numbers 1-27 will represent the rows and letters A-Q will represent the columns.

After being positioned on the device, the mouse’s limbs will be restrained with bands that have a peg on each end. The pegs on the end of each band will fit precisely into any hole on the peg board. The band will be made of a rubber material so that it is not too uncomfortable for the mice and so that it can be cleaned if exposed to radioactive materials. Only four of these bands will be necessary at any given time, but several different sets will be made to accommodate different sized mice. After the pegs are placed in the holes, the exact hole can be noted for the correct positioning of the mouse in future scans. Since the board is flat, the mouse’s body can be outlined with a wax crayon, EXPO marker, or permanent marker on the board to enable repositioning of the body in future scans. If the mouse’s body is traced, multiple devices would have to be fabricated for the lab because each mouse would need its own board. After the mouse is no longer a part of the study, however, the board can be reused. Since the lab does serial scans of 3-10 mice at a time, a maximum of ten boards would have to be fabricated.

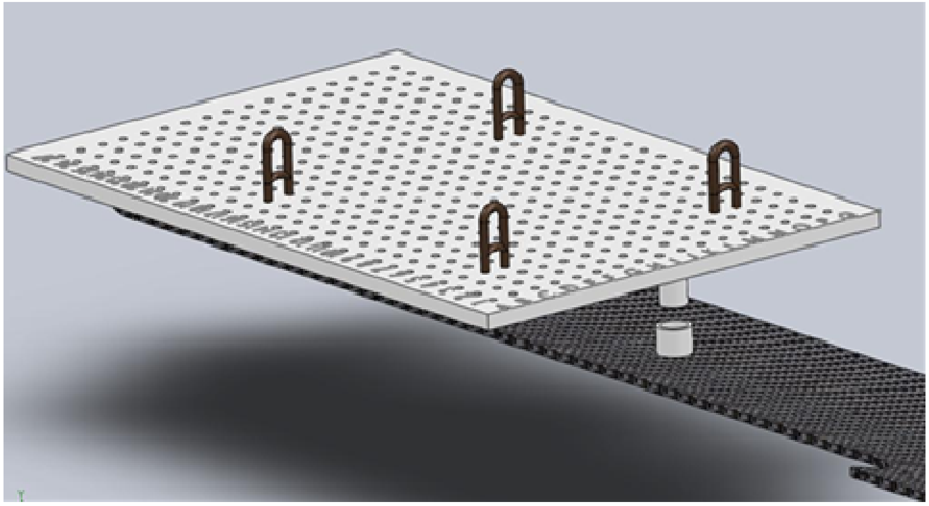

Figure 8: Peg Board Design

Evaluation of Design Alternatives

In order to choose the final design, a design matrix was created that rated each design alternative on six criteria: accuracy, ease of use/speed of attachment, animal safety, feasibility, sterility, and cost. More weight was given to more important criteria (Table 1).

The accuracy rating reflects the predicted ability of the device to replicate the position of the mouse during subsequent scans. This category was weighted the most because precise anatomical replication is the primary goal of the device. All three designs would be secured to the scanner bed using pegs glued to the underside of the device that would fit into slots on the existing carbon fiber bed. This would ensure that the device has the same position relative to the bed every time. However, the three designs differ in repositioning accuracy. The Velcro slot design would not replicate the mouse's position as accurately as the other designs, despite the measurement system alongside the slots. This is because the Velcro strips would not necessarily be secured around the animal’s limbs in the same location for each scan and the Velcro straps could possibly shift after being secured. The LEGO board design would be more accurate because the placement of the LEGO pegs could be exactly replicated each time. However, the male ends of the LEGO board are not close enough together to allow accurate placement of the pegs around the shape of the body. The peg board design would be the most accurate option because the pegs could be placed in the exact same position every time and the holes in the board would be close enough together to allow accurate placement of pegs around the body. The peg board would also be flat, allowing lab personnel to trace the body of the mouse. This would make it easier to replicate the position of the mouse’s body and limbs.

The ease of use/speed of attachment rating reflects the predicted efficiency of attaching the mouse to the device and attaching the device to the bed. This category was given more weight because efficiency is another important goal for the device. A shorter attachment time will reduce the overall duration of the scanning process and lower the chances of the mouse dying due to loss of body heat. The Velcro slot design would have a difficult attachment process because each Velcro strap would have to be woven down through one slot, up through the other, and then connected around the mouse's leg or arm. This would require two hands and careful manipulation of the straps. The LEGO board attachment process would be much more efficient. LEGO pegs could be placed with one hand, and the attachment locations would be easy to record. The peg board design would be slightly more difficult to use because the holes would be closer together than the LEGO attachments and would also be very small, requiring more concentration to place the pegs.

The animal safety rating reflects the predicted safety of the mouse during attachment and scanning. The two issues considered were the ability of the device to restrain the mouse if it were to wake up during a scan and the comfort level of the straps on mouse's limbs. While animal safety is a very important part of the design, it was not given a lot of weight because all three designs would be sufficient to restrain the mouse. The mouse would have very little ability to escape the Velcro slot design because the Velcro straps would be wrapped tightly around its arms and legs. However, the Velcro material is rough and could cause some discomfort. Both the LEGO and peg board designs would use a rubber strap that would be more comfortable than the Velcro strap, and still secure the mouse's limbs. One concern with the peg board design is that if the pegs do not fit tightly into the holes, it would be easier for the mouse to escape if it woke up.

The feasibility rating reflects the team's predicted ability to fabricate a prototype of the design before the end of the semester. All three designs would be possible to fabricate so feasibility was not as heavily weighted in our final design selection. The Velcro slot design would be the most difficult to fabricate because eight thin slots would have to be cut in the board. The LEGO board design would be the easiest to fabricate because the LEGO board and LEGO pegs are existing products. Only fabrication of the strap would be necessary. The peg board would be slightly more difficult to fabricate because holes would have to be drilled in the board in addition to the fabrication of the straps.

The sterility rating reflects how easy it would be to clean the device. While the ability to clean the device is a requirement for the device, it is not one of the main goals of the project and was not given a lot of weight. The Velcro slot design would be hard to keep clean because Velcro is not smooth and would be hard to wipe off. The LEGO board would be able to be wiped off but the raised and indented parts on the board would be hard to wipe completely. The peg board would be easier to clean because it would be a completely flat surface.

The cost of the device was not an important factor in our decision because the materials that will be used are very cheap and well within the $100 budget. The Velcro slot would be more costly because the Velcro straps would have to be replaced if they became unsterile.

Table 1: Design Matrix

Criteria	Velcro Slot	LEGO Board	Peg Board
Accuracy (35)	20	25	33
Ease of Use/Speed of Attachment (20)	12	18	16
Animal Safety (15)	12	12	10
Feasibility (15)	10	14	12
Sterility (10)	8	9	10
Cost (5)	3	5	5
TOTAL (100)	**65**	**83**	**86**

Final Design

We chose the peg board design as our final design because it meets our client's needs, is the most accurate, and will be the easiest to sterilize. The accuracy of the peg board design will be sufficient because positioning of the mouse will be exact from scan to scan. If the user records the coordinates of each arm and leg peg after positioning the mouse on the device for the very first time, the user will know exactly where to put the arms and legs on the device for every proceeding scan. After the arm and leg coordinates have been recorded, the user will use a wax crayon, EXPO marker, or permanent marker to outline the body of the mouse. This will ensure the mouse's body position is exactly like it was in the preceding scans. The device will be accurately positioned on the bed of the scanner via the two male pegs on the device and the two female fittings on the bed of the scanner. When the device is positioned on the bed, it will be in the exact same spot every time. Then the user will use the zeroing lasers on the scanner to put the bed of the scanner in the correct location. This method will ensure the mouse is positioned in the exact spot every time it is scanned. The peg board design is more accurate than the LEGO board design because the increments between coordinates are much less. It is more accurate than the Velcro slot design because the Velcro slot design is prone to user error when attaching the mouse to the device.

The speed of positioning the mouse in the scanner will be greatly increased with the peg board design in comparison with the current method. One of the main problems with the current method is the use of tape to restrain the animal on a cardboard sheet and to connect the cardboard sheet to the scanner bed. The tape often sticks to the wrong part of the bed, the animal, or itself while the user is trying to attach it to the animal. With the peg board, the pegs will be easy to push into the correct positions in a timely manner. The user will know exactly where the mouse has to go so it will not take as long trying to reposition the mouse over and over again in order to get it to line up with the preceding scans. The user will also be able to detach the mouse quickly by simply pulling the pegs out. The user will not have to pull tape off the bed or the mouse. It will also take less time to attach the peg board to the bed than the current method. The peg board design will simply sit into the two female fittings on the bed. The current method requires taping the cardboard sheet the mouse is restrained on onto the scanner bed. It takes too much time to get the cardboard sheet in the exact position every time. The LEGO board design would take less time to attach the mouse because the increments are bigger and it is easier to line up the pegs. The Velcro slot design would take longer because it would be hard to hold the mouse limb in the correct position and put the Velcro around it at the same time.

The peg board device will effectively keep the mice safe from injury. The restraint pegs will not allow them get up and fall into the scanner if they wake up during the scans. The restraint bands will be made of rubber so that the mice's limbs will not be crushed when the pegs are put into the peg board.

The peg board device will be feasible to fabricate because it does not involve complex machining and materials. ABS is a readily available plastic that is easily machinable. The only machining necessary is the drilling of the holes in a grid pattern. This can be done with a CNC mill available to the team in the student machine shop.

The device will be easy to sterilize. It will be able to withstand continual cleaning with the cleaning solution Lift-Away and the device will not be damaged. The device is smooth and will be easy to wipe off. The Velcro design would be hard to sterilize because the Velcro would retain small particles that cannot be wiped away. The LEGO board design would also be harder to sterilize because it has many ridges on the top surface and many craters on the under surface. These obstructions would make it hard to wipe the LEGO board clean.

The cost of all three designs will be minimal (Table 2). Each design involves the use of ABS plastic which is inexpensive. A 12"x12"x.125" sheet of ABS plastic can be bought for a price as low as $7.76 from McMaster-Car [6]. This is enough material to make six peg board devices not including pegs and bed connectors. Production costs for the LEGO Board and the peg board designs will be almost identical. The Velcro slot design will be more expensive to maintain because it would require the continual purchase of Velcro strips to replace the old ones when they become unsterile.

Table 2: Material Cost

Item/Material	Cost of parts for 1 prototype
ABS Plastic	$1.29
ABS tubing 0.125” inside diameter .25” outside	$0.03
Carbon Fiber Rod 0.0625” diameter	$0.96
Carbon Fiber Rod 0.125” diameter	$0.37
Elastic material for pegs	Unknown per prototype
ABS Glue and super glue	Unknown per prototype
	Total per prototype: $2.65 Added costs: material shipping, glue, and elastic peg material charges *all prices are based off McMaster-Car [6]

Obstacles to Overcome

Although the chosen design represents an achievable goal for the team, some problems may arise, especially concerning the making of the pegs and attaching the female fittings to the bed of the scanner. The smallest diameter rod of ABS readily available for purchase is only 0.25” [6]. The diameter of the pegs needs to be 0.0625”. Another potential problem is selecting a material to go between the pegs to restrain the mouse. The material should not be denser than ABS. It also needs to be flexible in order to not crush the mouse’s limbs when inserting the pegs into the holes. The material cannot be brittle, because the diameter of the pegs is small and if the material is too brittle the pegs would be easily broken. Attaching the female fittings to the bed may be a problem if the adhesive used is more dense than the carbon fiber bed, because if the adhesive is more dense then the carbon fiber bed, the adhesive will attenuate and interfere with the scan.

Ergonomics

The device incorporates many aspects of universal design. The device will be symmetrical to encourage equal use from left-handed and right-handed users. The user should be able to attach and remove the pegs, the mouse, and the device with minimal effort. However, the small size of the pegs may hinder ease of use. This problem is being considered in our future work. Minimal moving parts will make the device intuitive to use and will avoid any user confusion. To accommodate users of all literacy abilities, there will be no writing on the device except numerical and letter coordinate indicators. It will also be simple enough that an instruction manual on how to use the device could consist of pictures with no words to demonstrate each step of use. The device will consist of simple parts that are easily taken apart and put back together for cleaning and repairing.

Fabrication Process

The first step in fabricating the device is to cut a sheet of ABS plastic to the following dimensions: 0.125”x 5.4375”x3.5625”. Then the ABS will be put into a CNC mill and 0.0625” diameter holes will be drilled 0.125” apart in a grid system starting 0.25” away from the edges of the sheet. The grid system will be given coordinates by a marking device that will not wash off during sterilization. The next step will be to glue pegs to the bottom of the sheet with one on each end. The female attachments will be made from ABS tubing with the inside diameter the same as the diameter of the male pegs on the bottom of the device. They will be cut to length and glued onto the bed of the scanner with a strong adhesive. The fabrication of the pegs is still to be determined. One option is to buy a carbon fiber rod with a diameter of 0.0625” and cut them to length. Another option is to handcraft pegs from ABS plastic with a Dremel tool or a mill, but this will be hard to do. A stretchy material needs to be determined to go between the pegs. This will be attached to the pegs with glue.

Testing

The peg board will be easily tested for accuracy and attenuation. To test the accuracy of the device, the team will: attach a mouse to the device, record the coordinates, outline the body, attach the device to the scanner bed, align with the lasers, and then scan the mouse. The mouse will be taken off the device, repositioned and scanned again. This will be done many times in succession. After all the scans are complete, the images will be compared and differences of body position between scans will be measured using the computer software that is currently used to align images. This will give the client and the team an idea of how accurate the device is. The materials will be tested by scanning the device. If the device attenuates the image less than the carbon fiber bed, then it will be considered a success. This will be done by visually comparing the scanned image of the device to the image of the carbon fiber bed.

Ethical Considerations

The device will be used for medical research on live animals. The device must conform to RARC and lab protocols for animal safety to make certain the device does not harm the animal subjects [2]. This will ensure that the device is ethically allowed for research.

Future Work

The next steps to complete the project are to build a prototype and test the prototype. The team needs to determine what type of ABS will work best in the scanner. ABS can have different proportions of chemicals ranging from 15% to 35% acrylonitrile, 5% to 30% butadiene, and 40% to 60% styrene [4]. Because of this variation, it would be best if the team could test different kinds of ABS to see which attenuates X-rays less.

One thing that still needs to be decided is what type of pegs and bands to use. The pegs for the peg board have to be smaller than 0.0625” in diameter which may make it difficult to find something strong enough that is that small. The team also has to determine how the bands will be attached to these small pegs. The pegs that will attach to the bottom of the device and the pieces that will be glued to the bed also have to be determined. The size of these two pegs is still undecided as well because the pegs must be small enough to fit into the drilled holes, yet large enough for easy usage. After fabricating the device, the team will want to the test the device.

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Appendix

Product Design Specifications: Mouse Restraint Device

October 8, 2009

Eamon Bernardoni, Vanessa Grosskopf, Jim Mott, Samantha Paulsen, Brooke Sampone

Problem Statement:

The Small Animals Imaging Lab located in the Wisconsin Institutes for Medical Research is in need of a solid, adjustable device that will restrain mice during Positron Emission Tomography and Computerized Tomography (PET/CT) scans. These scans are used to pinpoint cancerous growths within the animal prior to treatment. The device must restrain the animal's extremities to prevent movement and must include a quantitative analysis device to replicate the animal's exact anatomical position. The device should improve efficiency for animal restraint compared to the current cardboard restraint device.

Client Requirements:

• Adjustable device to fit mice and accommodate 20-50 grams
• Device should be 5"- 6" in length to fit a mouse
• Device should not interfere with nose cone
• Device should include measurement device to replicate exact position of mouse
• Material should not interfere with imaging from PET/CT scanner and should not include cloth
• Method of restraining animal should take no longer than 10 minutes
• Device should prevent the animal from leaving the bed in the event that it wakes up
• Must attach to carbon fiber bed

Design Restraints:

1. Physical and Operational Requirements

a. Performance requirements: The device should accommodate mice ranging in size from 5"-6" in length and 20-50 grams. The mouse should be restrained in less than 10 minutes. 3-10 mice will be scanned several times over a period of roughly two weeks. 100 animals per year are scanned by the PET/CT machines. The device should be securely attached to the bed.

b. Safety: The device should conform to RARC and lab protocol. No animals should be harmed by the device. Absorbent material should not be used as to prevent retention of radioactive substances.

c. Accuracy and Reliability: The device should allow for the exact alignment of the anatomical position of each mouse over the duration of the study within 1 mm of the original position of the animal. Lasers are used to help align the position of the animal once it is attached to the bed.

d. Life in Service: The device will be used for approximately 400 hours each year.

e. Shelf life: If sliders are incorporated in the design, lubrication of the device may be necessary. Depending on the type of attachment, attachment material may need to be replaced once worn.

f. Operating Environment: The device will be used in the research laboratory. There may be corrosion of materials due to lubrication of the device and radioactive liquids.

g. Ergonomics: The device should be attached with minimal effort in a matter of 5-10 minutes. The size settings should not cause eye strain. Animal position should be easy to replicate.

h. Size: The device should be no more the 0.5" thick or 3" wide. The length should not exceed 12".

i. Weight: The device weight should be less one pound.

j. Materials: The materials used in the device should not interfere with the imaging procedures. Cloth should not be used. Carbon fiber would be the preferred material.

k. Aesthetics, Appearance, and Finish: The device should be neutral in color, smooth, and have no sharp edges.

2. Product Characteristics

a. Quantity: The client requires one device.
b. Target Product Cost: $100

3. Miscellaneous

a. Standards and Specifications: The device must comply with RARC and lab protocol for animal safety.

b. Customer: The device will be used in the Small Animal Imaging Lab at UW-Madison for PET/CT scans.

c. Patient (animal)-related concerns: The device must be wiped down between animals.

d. Competition: Due to the fact that the device is custom to this specific research lab, there is no foreseen competition.