Arm Holder for a CT Scanner

Final Design Report

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ABSTRACT

Cardiac computer tomography scanning is an imaging technique that is becoming widely used. The process involves emission and detection of x-rays sent through the patient to image internal organs and arteries to aid in diagnosis of cardiac diseases. To produce the best image with minimal motion artifact, the patient's heart rate needs to remain low by keeping the patient comfortable and relaxed. One factor currently contributing to patient discomfort is the lack of support and positioning of the arms, which must be held above the patient's head throughout the procedure. To do this, our client would like us to construct an adjustable arm rest with sufficient forearm support for the user. Based on our client's requirements, we formulated three designs based on a common wedge configuration. Our final design has wedge angle adjustment and handlebars with rotational and distance adjustment options. Future work for this project includes finding materials that are radiolucent and creating a wedge-shaped cushion to complement this design and improve patient comfort.

BACKGROUND

Problem & Motivation

In computer tomography (CT) scanning, digital geometry processing is used to generate 3D images. The digital data is collected by a series of x-ray plates that rotate around the patient at high speeds, allowing the device to complete a chest scan, for example, within 15 seconds. However, to produce the best quality images using the CT scanner, the patient must be stable and relaxed to minimize movements. Respiration, cardiac motion, and patient restlessness produce blurring, doubling, and distortion artifacts in the reconstructed images and may lead to misdiagnosis [1]. In one study, images of anesthetized patients still resulted in a 0.1mm error and 0.6-1.4mm error for non-anesthetized patients [2]. For cardio and respiratory applications of CT scanning, beta blockers are given to the patient to help keep his or her heart rate below 60 beats per minute. A low heart rate prevents the patient's internal organs from excessive motion that can cause blurring in the final image.

To help maintain the patient's low heart rate and to restrict body movement, the arms must be comfortably supported and stabilized above his or her head, thus keeping them away from the scanning area (the patient's chest) during the twenty minute procedure. Since the scanning bed does not have a way of accomplishing this arm support, our client would like a device that can comfortably support and minimize movement of the patient's arms throughout the procedure. To prevent the intravenous (IV) line delivering the beta blockers to the patient from pinching, the inner elbow should bend less than ninety degrees and be accessible. Most of the patients are between 40 and 80 years of age and the device must accommodate individuals with restricted shoulder rotary motion. The device should be adjustable to accommodate all body sizes. The device must remain stable on the scanner table, have customizable height and grip angle adjustments, and provide support to the patient's forearms. The device should be manageable by a single nurse and easy to store. The device should also be sturdy and fit on the bed of a CT scanner such as those produced by General Electric (GE).

Overview

The device would enhance patient comfort during the twenty minute scanning procedure, keep the IV connected to the patient's arm easily accessible, and reduce unnecessary arm movements. This would subsequently help the patient maintain a low heart rate and thus reduce the amount of image artifact in the cardiac tomography output image.

Cardiac Computed Tomography (CT)

Figure 1. CT Scanners produced by GE, Phillips, and Siemens.

CT is a medical imaging method that uses digital imaging processing to construct a three-dimensional image of an object using a series of two-dimensional X-ray images around one axis [3]. For cardiac CT scans, the final image construction can visualize arteries and detect plaque buildup, stenosis, or blockage within them.

During a cardiac CT scan, the patient must lie down on their back on the scanning bed (Fig. 1). An IV is hooked up to their arm to administer beta blockers. Beta blockers are drugs that block the stimulation of beta-receptors in the heart's myocardium (middle layer of the heart wall) by the central nervous system, thereby lowering heart rate and blood pressure. For this cardiac CT scanning procedure, the goal is to lower the patient's heart rate to 60 beats per minute. This heart rate reduction is necessary in order to reduce image artifact and allow the arteries to be detected clearly in the image. The patient is then asked to stretch their arms back behind their head in order to keep their arms out of the scanning area.

Setting up the patient and the equipment takes approximately fifteen minutes, although the actual data collection process takes roughly 7-10 seconds. The CT scanning bed slowly slides the patient through the CT scanner's gantry. It collects thousands of data points along a single rotary axis around the patient which are then reconstructed into a three dimensional image by a computer. When the scan is complete, the scanning bed slides back out. The patient is then detached from the IV and can return home between one and two hours after entering the clinic.

Range of Motion (ROM)

Most of the patients undergoing a cardiac CT scan are elderly and may have ROM problems in their joints. Studies have shown that older adults have less ROM of the extremities than younger adults, including less elbow motion and decreased shoulder rotation [4]. Shoulder joint motion studies typically examine a variety of shoulder movements including elevation, extension, medial rotation, lateral rotation, and abduction. Normal ranges of motion for these measurement categories for a group of healthy young males and those for older adults are shown in Table 1 below:

	Elevation	Extension	Medial Rotation	Lateral Rotation	Abduction
Young Adults ***(20-50 years)***	167°	62°	69°	104°	184°
Older Adults ***(61+ years)***	152-160°	13-23°	44-62°	46-62°	152-162°
Difference	**7-15°**	**39-49°**	**7-25°**	**42-58°**	**22-32°**

Table 1. Normal ranges of motion for young adult males, older adults, and the changes in these ranges [4, 5].

These rotational restrictions limit how far a patient can reach back behind their head and rotate their shoulders outwards in order to keep their arms away from the cardiac scanning field.

Design Constraints

A variety of constraints are addressed to ensure the highest design quality and the safety of the patients. The two CT scanning tables used at University of Wisconsin hospital are GE Lightspeed VCT 64-slice scanners. GE scanner table width is 16.5 inches with a concave table surface to cradle the patients' body. However, the final prototype can be developed to comply with many different scanner brands (i.e. Toshiba, Phillips, and Siemans).

Most importantly, we must assure the patient's safety. The device must be reusable up to twenty procedures per day. Material decisions must consider recurrent patient contact and sustain frequent cleaning by chemical disinfectant sprays and ethanol. The design should have no sharp edges that could come in contact with the patient or the personnel operating the device.

During the scanning period, approximately fifteen to twenty minutes, the patient's comfort is the main concern. Each patient may require different angles and/or distance to remain comfortable. Therefore, the client has requested the maximum degrees of freedom as possible. Many of the elderly patients have restricted joint rotation and may require special consideration.

For the convenience of the nurses and in order to expedite the procedure, the device must be maneuverable by one staff member during set up and take down. It should weigh less than thirty pounds and be small enough to hang on the wall or conveniently stow away.

Current Devices

A series of web searches and communication with the client revealed that there are no arm rests on the market specifically designed for CT scanners. Since there were no available products, a wedge shaped padded device provided by GE is commonly used (Fig. 2). The patient simply rests his or her arms on the wedge during the procedure. Based on a device used by some of his colleagues in Germany, our client built two versions of an armrest that are currently in use at UW-Health. Version 1 of the armrest is made from PVC tubing and is a simplistic design with an angled handle bar (Fig. 3a). Similarly, version 2 is also made from PVC tubing, but has a straight handle bar (Fig. 3b). Since both versions of the device are not adjustable, problems may arise for individuals with limited range of motion needing to use the device. Our client informed us that most of his patients are above the age of 40, hence it is imperative to develop a device that comfortably accommodates patients with various ranges of

Figure 2. Padded wedge currently used for arm positioning and support.

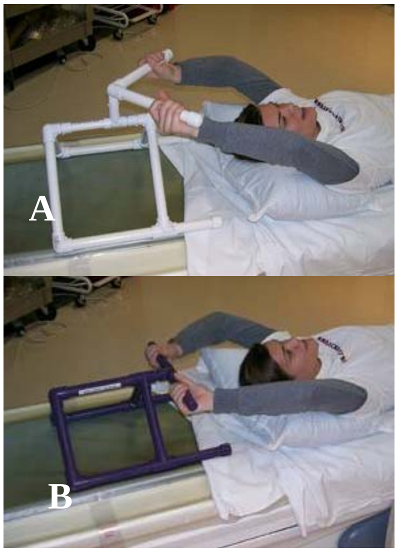


Figure 3: Team member demonstrates versions one (A) and two (B) made by client.

motion. Furthermore, neither version provides sufficient support in the forearms, which increases patient discomfort. The only differences between the two versions are the orientation of the handle and the rigidity of the device. Both armrests are secured onto the CT scanning table using Velcro straps purchased with the scanner. Unlike version 1 where the handle is offset from the base at a certain height, the handle bar on the second version is directly attached to the base of the unit. The direct attachment of the handle to the base improves the rigidity of the device, which allows fewer movements during the procedure and consequently aids in producing higher quality images.

MATERIAL CONSIDERATIONS

Since CT scanners are essentially X-ray machines that send several X-ray waves at different angles, there are very few restrictions on the type of materials used for the armrest [3]. Unlike with MRI machines, ferrous materials may be used with CT scanners, which further alleviate restrictions on the possible materials to use for the device. The materials used in building the device must be sturdy enough to support patients' arms, durable for repeated use, and be able to withstand hospital antibacterial disinfecting agents. Material density should be considered, as it will directly affect the weight and stability of the device.

Expanded rigid polyvinyl chloride (PVC) sheets are sturdy, but are also easy to machine, which make them ideal candidates for the device. Hence, PVC is the major component of the device and is used to form the frame [6]. Copper pipes were used to construct the handles, and vinyl grips were used to cover the handlebars for comfort and easy cleaning between uses. To provide support for the forearms, foam padding material is attached to the top side of the PVC wedge. The foam allows the patient to comfortably rest their arms. To properly disinfect the device between uses, the padding is covered with a vinyl material. Since foam padding is absorbent, the vinyl will serve as a barrier to prevent spread of infection from other patient's open wounds or sores.

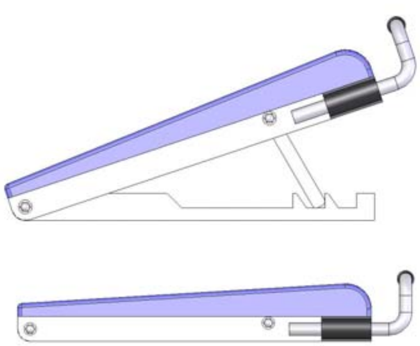


Figure 4. (Top) Sliding handlebar design in unfolded position. Vertical support is sitting in middle position. (Bottom) Sliding handlebar design in flat storage position.

ALTERNATE DESIGNS

The three designs are all variations of one general design. The general design combines the padded wedge currently used in positioning the patient with the addition of an adjustable handle. The wedge is designed to be angle and height adjustable and uses a reclining mechanism much like that of a beach chair (Fig. 4). Two parts of the frame are attached at one end through a pivot point allowing them to rotate freely. The bottom section of the frame has three indents in which a hinged vertical support attached to the top frame may fit. By changing which slot the support sits in, the angle and consequently the height of the wedge can be adjusted. The wedge frame is also designed to fold flat (approximately 3.5 inches) as in the bottom of figure 5. The is constructed of rectangular PVC stock of varying widths and secured by screws, PVC cement, and bolts. A padded surface is attached to the top frame. This will consist of foam padding on top of a thin board. An easy to clean material such as vinyl will be used to cover the foam padding. The padded top will have arm indentations to aid in restricting patent movement. A small padded flap (not shown in Fig. 5) will be added to the front of the wedge to protect the patient's back when lying against the front edge of the frame and continue the wedge shape to the table top. The three designs arise by varying handle adjustment mechanisms. Each variation is discussed in the following sections.

There are several benefits to this general design. First, the design incorporates several positioning mechanisms making it easy for a staff member to handle and set up. It folds flat and is convenient for out of the way storage on a wall or in a cabinet. The angle adjustable wedge allows greater ranges of positioning than the current padded wedge. Padded arm indentations help support and restrict the patient's forearms which previously had no support. The handlebar also allows the patient to comfortably rest and steady their hands. There are a few disadvantages to this design. It assumes all patients will have their shoulders just before the wedge with their head resting at the base of the wedge. This position does not work for all patients who are not comfortable lying completely horizontal since it cannot be used as a back support like the current wedge. This is because the handlebar would interfere with the patient's placement on the device.

Design 1: Rotational Handlebar

The first variation is the rotational handle design which uses two hinges that can be locked at any angle **(**Fig. 5). These hinges are attached to the back side of the top frame and handlebar support. The handlebar is bent into a long U-shape and placed in two holes in the handlebar support. A long vinyl grip or grip tape covers the handlebar for extra comfort.

A benefit of this design is that the handlebar has some distance and height adjustment. The hinges can be locked within a 90 degree range. The easy lock hinges are also simple to use and quickly set up. However, since the handlebar is constrained to rotation about the hinges, only a single height is available for a certain distance and vice versa. This design also requires the locking of two hinges instead of one as with the sliding handlebar design. Pinching may also be a concern while adjusting the hinges.

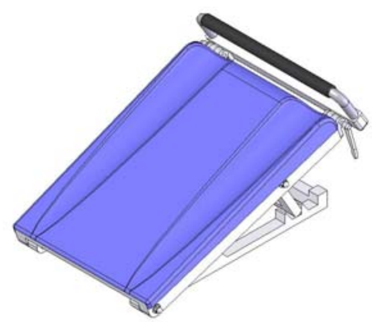


Figure 5. Rotational handlebar design with locking hinges.

Design 2: Sliding Handlebar

The second design is the sliding handlebar design (Fig. 6). The handlebar is constrained so that it may slide and adjust to a desired distance. The two ends of the

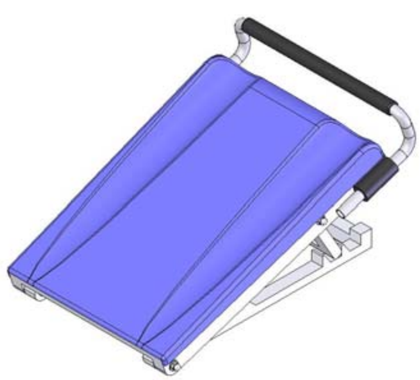


Figure 6. Sliding handlebar design with circular clamps.

handlebar fit into round clamps on both sides of the top frame. These clamps squeeze the handlebar when tightened much like a bicycle seat mechanism. Again a vinyl grip or grip tape will be used on the handlebar to ensure patient comfort.

This design has several advantages over design 1. The handlebar distance can be adjusted up to three inches parallel to the top of the wedge, allowing the patient to find his or her most comfortable setting. This design also requires only one side of the clamps to be tightened. This would be more convenient for the worker by simplifying the set up procedure. This design also has some drawbacks. The handlebar distance in the plane of the wedge can be adjusted; however, perpendicular height adjustments cannot be made.

Design 3: Rotational & Sliding Handles

The last variation is the rotational and sliding handles design (Fig. 7). This uses the same clamping mechanism as the sliding handlebar design but has two separate handles. Dividing the handlebar allows rotation and permits the patient to supinate and pronate their arms. The distance could also be adjusted by sliding the bar through the clamp. Clamps on both sides of the frame need to be tightened to lock them into place. Alternatively, the handles may be angled forward to accommodate slightly bent elbows. Each handle would have a grip for maximum comfort.

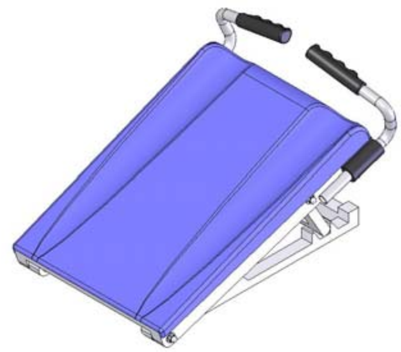


Figure 7. Rotational and sliding handles design with circular clamps.

There are several benefits to this design. Of the three designs, this design has the greatest degree of adjustability. It allows arm rotation, distance adjustment, and is the only design with the option to angle the handle to accommodate slightly bent elbows. However since the handles are separate each locking mechanism must be tightened, thereby adding complexity that could increase the cost of the device and set-up time.

DESIGN MATRIX/PROPOSED DESIGN

All three proposed designs were judged on four categories: comfort, adjustability, portability and ease of manufacturing. Since our client was most interested in maximizing patient comfort and the ability to adjust to patients with varying ranges of motion, those two categories were weighted slightly more than others (Table 2). The device may not be transported between each procedure, and therefore may not be required to move often. Consequently, portability is weighted less than comfort and adjustability. Ease of manufacturing was considered since we want to patent and market a finalized device, but this is not a primary concern relative to comfort and adjustability. Any given device can obtain a maximum of 100 points, and the device with the highest rating is more desirable than one with a lower rating.

Design 3, which has handles that rotate as well as vary in distance, would be the most adjustable and as a result, most comfortable of all the designs. The other two designs only have a single handle that can either rotate or change in distance. Further, the hinges in design 1 may pose a risk of pinching during use and hence was awarded the lowest score. Although all three designs can fold flat and be carried easily, the first two designs will be less compact when folded due to the nature of their handles. Since design 3 has two separate handles, it might be slightly more difficult to carry and transport it from one room to another. Finally, design 1 received the lowest score in ease of manufacturing since all parts of the frame must be perfectly aligned with the horizontal handle bar. The two lockable hinges further complicate manufacturing of the device. Moreover, the handle must be made from one rod that must be bent to the correct angles, and must remain parallel to the padding, further complicating construction of the device. Construction of design 2 would be very similar to construction design 1; however, it is rated higher since design 2 does not have the two hinges. On the other hand, design 3 has two separate bars that are free to rotate about the plane of the arm rest, and has two clamps that can be easily bolted to the frame of the device. Overall, design 3 received the highest score, and consequently was the design that was pursued during the semester.

	DS1	**DS2**	**DS3**
Comfort (30)	20	25	28
Adjustability (30)	20	25	30
Portability (20)	20	20	19
Ease of Manufacturing (20)	13	15	18
Total (100)	**73**	**85**	**95**

Table 2. Design matrix.

FINAL DESIGN

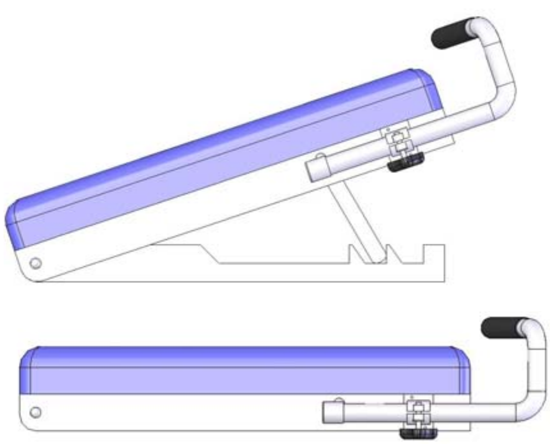


Figure 8. (Top) Side view showing wedge angle adjustment and hand tightened handle clamps. (Bottom) Device folds to 3.75 inches for easy wall or cabinet storage.

The final design combines the padded wedge currently used in positioning the patient and attached adjustable handles. The wedge is designed to be angle and height adjustable and uses a mechanism much like that of a beach chair reclining adjustment (Fig. 8). Two parts of the frame are attached at one end through a pivot point allowing them to rotate freely. The bottom section of the frame has three indents in which a hinged vertical support beam attached to the top frame may fit. By moving the support beam to different slots, the angle and height of the wedge can be adjusted (see Table 3). The wedge frame is also designed to fold flat (3.75 inches**).** The frame is constructed of 1.75” x 1” rectangular PVC stock and fastened by screws, PVC cement, and bolts. The frame was painted white and coated with clear polyurethane for aesthetics and protection. A padded surface is attached to the top frame. This consists of 2” foam padding affixed to a ¼” plywood sheet. Vinyl is stretched over the foam and stapled along the edge of the plywood. A small padded flap (not shown in Fig. 8) will be added to the front of the wedge to enhance patient comfort by filling the gap between the front edge of the device and the scanning bed.

Two separate handles are attached to the top frame via hand tightened clamps. The clamps allow unidirectional movement and rotational movement and constrain all degrees of freedom when tightened. This allows the handles to be adjusted both rotationally and laterally permitting the patient to supinate, pronate and stretch their arms to a comfortable position. These handles are made from ¾” copper tubing and 90° joints. They are soldered together at a 25° angle with the grips to provide a comfortable hand position. They are painted white to match the frame and vinyl grips fit over the tubing to provide a comfortable hold. For a comprehensive list of materials, vendors, and costs, see the Bill of Materials in Appendix A. To see more details on device dimensions, see the Device Schematics in Appendix B.

Prototype Specifications	
Weight	17.5 lbs
Fold Up Dimensions	18.25" x 22.5" x 4.0"
Wedge Angles	13.6°, 18.5°, 21.0°
Wedge Heights	8.6", 10.2", 11.0"
Handle Rotation	360°
Arm Length Adjustment	9"

Table 3. Arm rest specifications.

There are several benefits to this design over the current devices. First, the design incorporates several positioning mechanisms making it easy for staff members to handle and set up. It folds flat and is easily stored on a wall or in a cabinet. The angle adjustable wedge allows greater ranges of positioning than the currently used padded wedge. The padded top allows comfortable support for the forearms and shoulders. The shoulders of the patient may be positioned either just in front of the device or up on the wedge. The handles allow the patient to comfortably rest and steady their hands; this is not provided by the currently used wedge. Unlike the client’s previous versions, this device’s handles offer several adjustments to maximize patient comfort.

There are a few disadvantages to this design compared to existing devices. The device is mainly designed so the patient’s head rests on the foam padding and the shoulders rest next to the base of the wedge. For patients that need their shoulders propped up higher, this device would not provide proper support because although the wedge can be used to as a back support, the wedge then no longer provides forearm support. Parts of the device, such as metal screws, are also not radiolucent and therefore produce image artifacts in the CT scan. Although these artifacts do not interfere with cardiac image sections, they could interfere with other scanning procedures. This can be corrected by using different materials that have a higher radiolucency, or higher permeability to x-rays [7].

TESTING

Radiolucency

After using the device with patients during actual CT scans, the client decided to run only the prototype through GE’s CT scanner to see how radiolucent the device was. The client felt that the screws and bolts used to hold the prototype’s frame together introduced minor image artifact in the scanned image. The plywood board, vinyl, and foam padding have very high radiolucencies as these materials are not visible in the scan (Fig. 9). The PVC, staples, screws, and bolts used in this device are visible in the image and therefore have low radiolucencies. The client suggested using better radiolucent materials similar to those used in the scanning bed itself to eliminate the artifact produced.

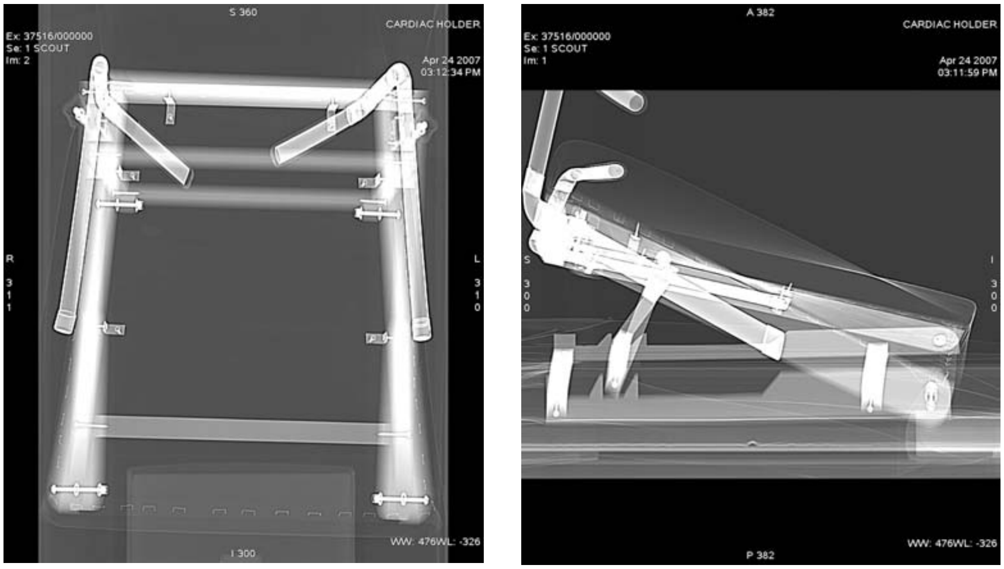


Figure 9. CT images of prototype to test radiolucency of materials.

User Testing

Ten subjects (5 male, 5 female between the ages of 19 and 60) tested our device (Table 4). At the three different height settings for the prototype, the shoulder abduction Measurements ranged from 139 to 170 (degrees). According to Table 1, this measurement for adults older than 61 years of age was between 152 and 162 degrees.

Subject Height	**Height Settings on Device**		
	Shortest (8.6")	**Middle (10.2")**	**Tallest (11")**
5"10	166°	163°	161°
5"11	162°	158°	155°
5"11	155°	154°	158°
5"2	154°	149°	143°
5"4	153°	149°	146°
5"9	141°	139°	150°
6"0	166°	163°	165°
6"1	168°	170°	165°
6"2	161°	155°	146°
6"3	165°	159°	160°

Table 4. Shoulder abduction angles in subjects of varying heights for all height settings on device.

Patient Testing with CT Scanner

The device was tested with two patients on the scanning bed. The client allowed the patients to place their arms at a comfortable position on the handle bar, and locked it in place. While adjusting the handle bar, however, some of the paint came off of the device. To prevent this from happening in the future, adhesive foam was added to the clamps. Patients held on to the device for the entire duration of the procedure (between 20-30 minutes), and did not complain of pain. Overall, the device seemed to fulfill its purpose and functioned properly during the procedure. Our client was also pleased with the device, and as described above, suggested that we look into replacing metal screws and bolts with radiolucent parts.

CONCLUSIONS & FUTURE WORK

After testing the device with patients on the CT scanner, it was evident that the parts of the device closest to the patient's chest are in the field of the scanner. Scanning the device indicated that the metal screws used in the frame of the device produced undesirable image artifacts; hence, the existing screws could be replaced with plastic screws or other materials with greater radiolucency. Though replacing the existing materials is not essential for cardiac CT scans, it will be beneficial if the device is used in the future for other CT scans. In addition, the current device is not completely flush with the scanning bed, which could discomfort the patient's shoulders and arms. Hence, a small wedge shaped cushion could be built for use in conjunction with the existing device. Also, handle could be attached to the device for ease of portability. This handle could also be used to hang the device on the wall of the CT room for storage. Alternatively, a new device could be built instead of modifying the existing device using materials that are more radiolucent to minimize artifacts and has padding that is flush with the scanner table.

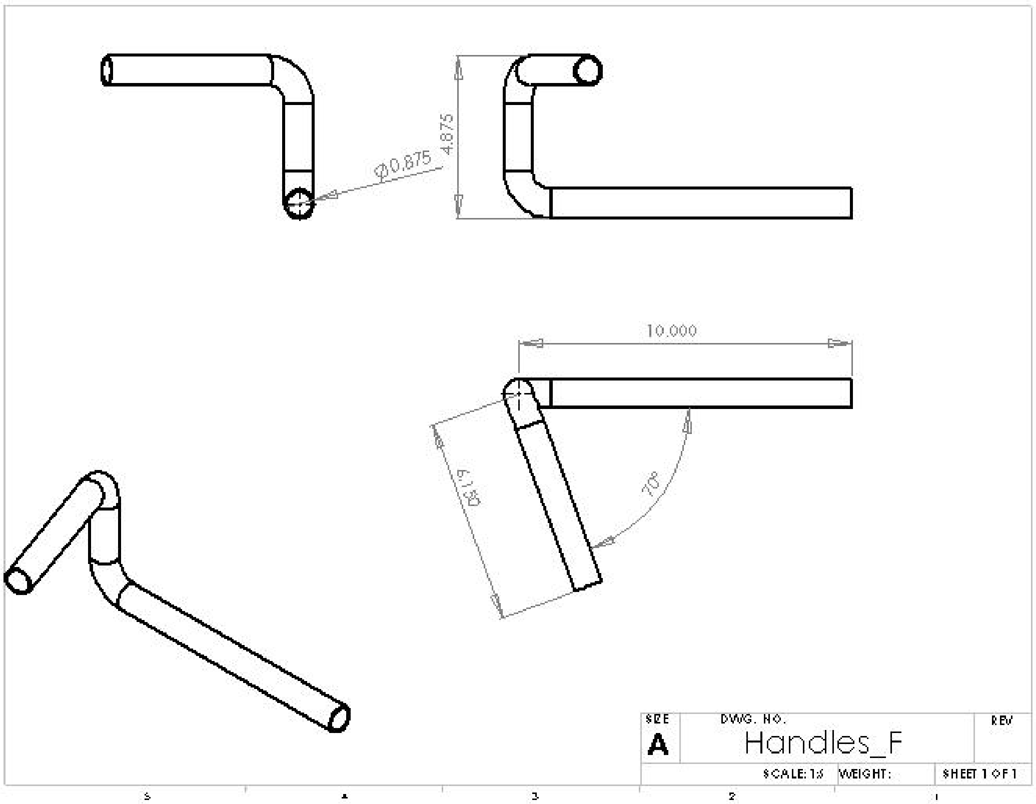
After making necessary modifications, the device will be further tested using human subjects. To determine the degree of comfort provided by the device, patients may be asked to complete a survey asking them to rate their comfort level when using the current device as compared to using pillows. The device will also be tested for durability to ensure that it can withstand wear-and-tear from daily use.

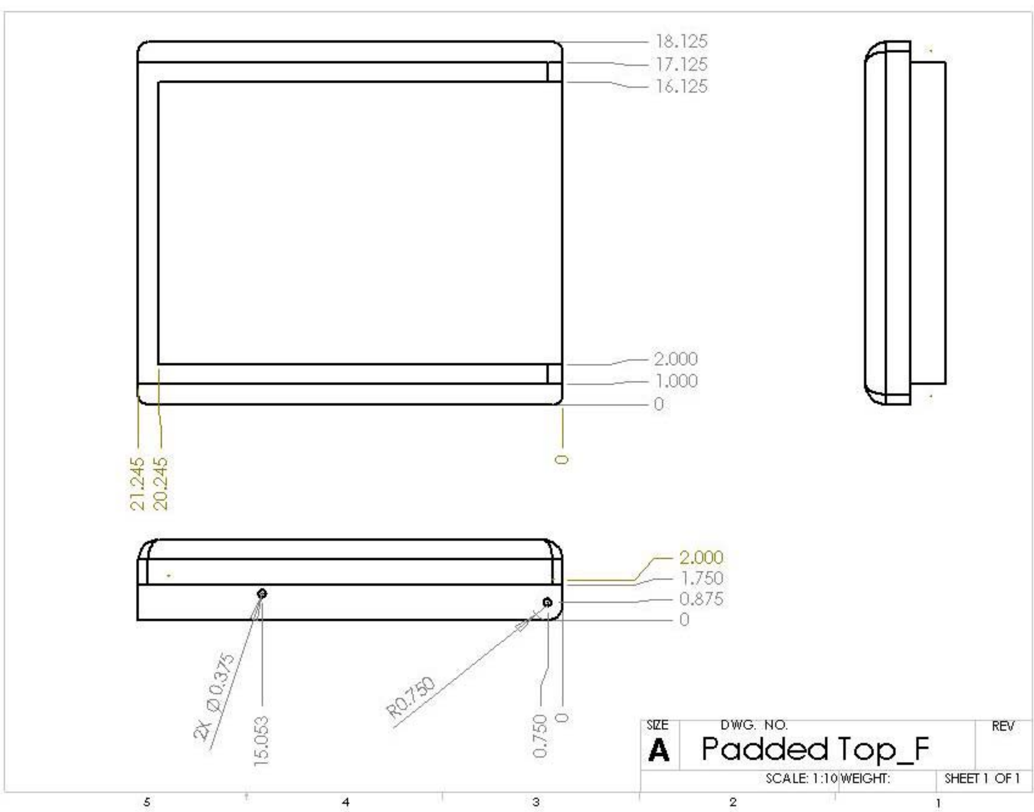
Once a final design has been fully tested and approved, a patent will be obtained through the Wisconsin Alumni Research Foundation (WARF). After patenting the device, further steps may include marketing the device and developing a manufacturing line for the final product.

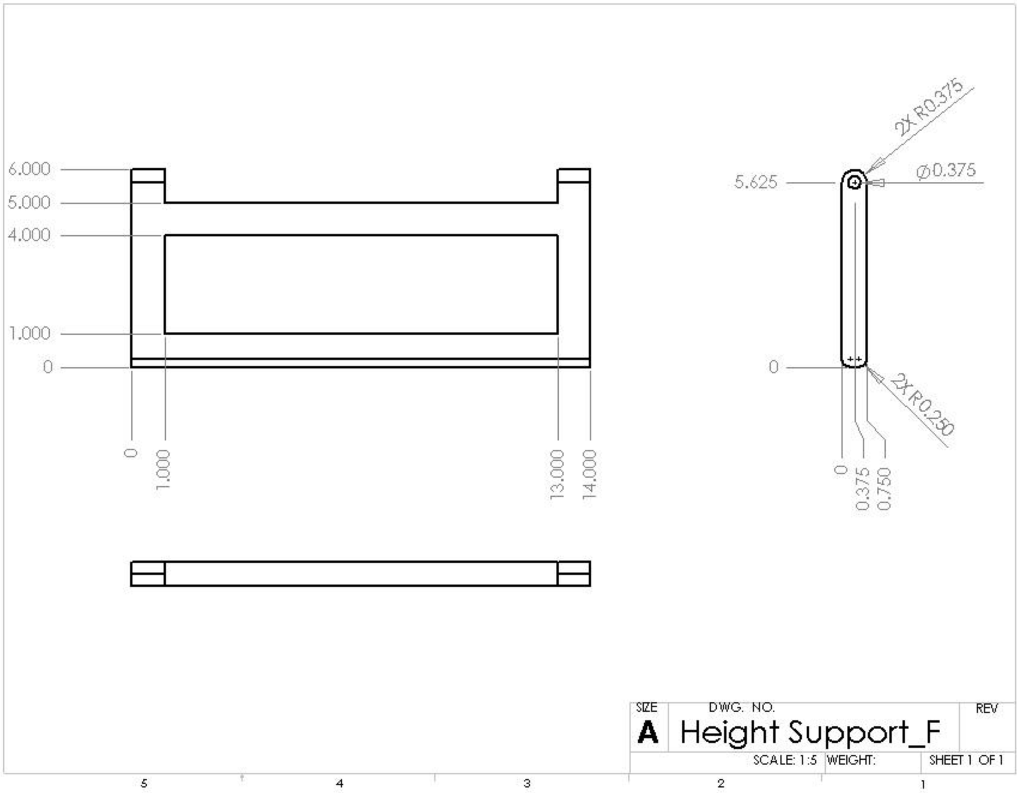
APPENDIX A – Bill of Materials

PROJECT COSTS					
Item	**Supplier**	**Item #**	**Quantity**	**Unit Price ($)**	**Total ($)**
2” Foam Padding	Jo-Ann Fabrics	2180289	0.833 yd	19.99/yd	16.65
Blue Vinyl	Jo-Ann Fabrics	3526415	1 yd	9.99/yd	9.99
Metal Pad	Home Depot	051144074143	1	1.86	1.86
Fine Sandpaper	Home Depot	051111115220	1	3.67	3.67
Coarse Sandpaper	Home Depot	041111115213	1	3.67	3.67
White Spray Paint	Home Depot	021200962622	1	4.78	4.78
Polyeurethane Spray	Home Depot	027426330504	1	5.97	5.97
PVC Cement	Home Depot	038753302478	1	5.48	5.48
Sandpaper (for metals)	Home Depot	020066779283	1	3.79	3.79
3’ 4x5 Copper Pipe	Home Depot	685768276494	1	9.92	9.92
¾” Copper Cap	Home Depot	685768204367	2	0.75	1.50
¼” 2x2 Plywood	Home Depot	099167465289	1	2.79	2.79
1” Corner Brace/Mounting Brackets	Home Depot	033923930291	2	1.69	3.38
¾” Copper 90d Elbow	Home Depot	685768203551	4	0.61	2.44
Flathead Screws, #8- 1½”	Home Depot	030699210923	1 pack	5.57	5.57
1/4"-2.5" machine screws	Home Depot	030699192618	3	0.98	2.94
1/4" ID, 3/4" OD Washers	Home Depot	030699198214	2	0.98	1.96
1/4" Locknuts	Home Depot	030699332816	3	0.98	2.94
Flathead Screw, #8- ½”	Home Depot	030699209514	1	0.98	0.98
Flathead Screw, #8- ½”	Home Depot	030699209217	1	0.98	0.98
Vinyl Hand Grips	McMaster-Carr	97065K53	1 pack	7.53	7.53
¾” Thick, 1” Width Gray PVC Type 1 Rectangular Bar	McMaster-Carr	8740K15	4 ft	3.38/ft	13.52
1” Thick, 1” Width Gray PVC Type 1 Rectangular Bar	McMaster-Carr	8740K16	2 ft	4.17/ft	8.34
1 ¾” Thick, 1” Width Gray PVC Type 1 Rectangular Bar	McMaster-Carr	8740K18	12 ft	10.27/ft	123.24
Nylon Bearing Sleeve, ¼”Shaft Diameter, 3/8”OD, ½”length	McMaster-Carr	6389K113	4 packs	2.15	8.60
Flange Clamp	Reid Supply	RKC-120	2	15.60	31.20
CUSHIONED SMOOTH SURFACE VINYL GRIP, FITS 7/8" OD, 5-1/16" LENGTH, BLACK	McMaster-Carr	97065K71	1 pack	7.18	7.18
Comfort-Grip Knobs, 1/4"-20 X 1.25" THREADED STUD, 1.75" DIAMETER	McMaster-Carr	2454K66	2	2.29	4.58
18-8 STAINLESS STEEL MACHINE SCREW NUT, 1/4"-20 SCREW SIZE, 7/16" WIDTH, 3/16" HEIGHT	McMaster-Carr	91841A029	1 pack	10.17	10.17
¾” Mini Flange Clamp	Reid Supply	RKC-115	4	12.00	48.00
½” Gray Vinyl Gasket	Menards	5672970	1	2.29	2.29
½” x 12” Repair Coupling	Menards	6874104	2	3.49	6.98
5” x 7” Tub Spout Elbow	Menards	6874036	2	2.99	5.98
½” Copper Cap	Menards	6871534	2	0.23	0.46
½” 90Degree Copper Elbow	Menards	6871343	2	0.30	0.60
½” x 5’ Copper Pipe	Menards	6873202	1	6.96	6.96
Foam	Michaels Crafts	652695134074	2	0.79	1.58
Poster	CIMC	N/A	5.5 feet	$4/linear foot	22.00
				Shipping	38.91
				TAX:	6.39
				GRAND TOTAL:	**445.77**

APPENDIX B – Design Schematics



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0
0.375
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REV
A
Height Support_F
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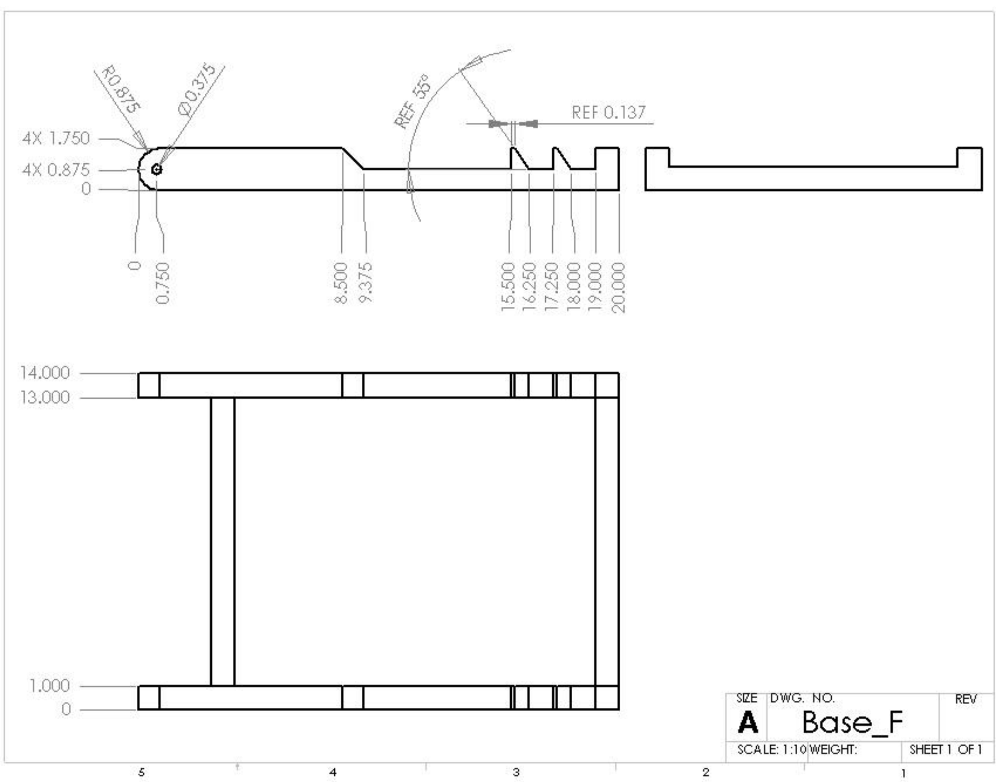
WEIGHT:
SHEET 1 OF 1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17.250
18.000
19.000
20.000
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A
Base_F
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SHEET 1 OF 1

APPENDIX C – Product Design Specifications

Arm Holder for Cardiac CT Scans

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May 4th, 2007

PURPOSE & DEVICE FUNCTION:

In computer tomography (CT) scanning, digital geometry processing is used to generate 3D images. The digital data is collected by a series of x-ray plates that rotate around the patient at high speeds, allowing the device to complete a chest scan, for example, within 15 seconds. However, to produce the best quality images using the CT scanner, the patient must be stable and relaxed to minimize movements. Respiration, cardiac motion, and patient restlessness produce blurring, doubling, and distortion artifacts in the reconstructed images and may lead to misdiagnosis [1]. In one study, images of anesthetized patients still resulted in a 0.1mm error and 0.6-1.4mm error for non-anesthetized patients [2]. For cardio and respiratory applications of CT scanning, beta blockers are given to the patient to help keep his or her heart rate below 60 beats per minute. A low heart rate prevents the patient's internal organs from excessive motion that can cause blurring in the final image.

To help maintain the patient's low heart rate and to restrict body movement, the arms must be comfortably supported and stabilized above his or her hear, thus keeping them away from the scanning area (the patient's chest) during the twenty minute procedure. Since the scanning bed does not have a way of accomplishing this arm support, our client would like a device that can comfortably support and minimize movement of the patient's arms throughout the procedure. To prevent the intravenous (IV) line delivering the beta blockers to the patient from pinching, the inner elbow should bend less than ninety degrees and accessible. Most of the patients are between 40 and 80 years of age and the device must accommodate individuals with restricted shoulder rotary motion. The device should be adjustable to accommodate all body sizes. The device must remain stable on the scanner table, have customizable height and grip angle adjustments, and provide support to the patient's forearms. The device should be manageable by a single nurse and easy to store. The device should also be sturdy and fit on the bed of a CT scanner such as those produced by General Electric (GE).

CLIENT REQUIREMENTS:

- Device should have minimal movement once it is attached to the scanning table.
- Should withstand hospital antibacterial disinfecting agents
- Must provide comfortable arm support for 20 minute procedure
- Keep arms out of the scanning field (the chest area)
- Compatible with General Electric's 64-Slice VCT Scanner
- Materials should be radiolucent, or have high permeability to x-rays

DESIGN REQUIREMENTS:

1. Physical and Operational Characteristics

    a. Performance Requirements

i. Reusable. The CT scanners at the UW Hospital in Madison, WI are used approximately 4-7 times per week. The entire device should be able to withstand this usage frequency without frequent maintenance or replacement (i.e., annual or more often).
ii. Withstands chemical disinfectant sprays and ethanol
iii. Sturdy; cannot shift on scanning table as a slight movement will distort or blur the image. The device should have minimal movement once it is attached to the scanning table to prevent image artifact from occurring.
iv. Should withstand the weight of the patient's arms without tipping, bending, or deforming (see b.ii below)

b. Safety
i. Non-toxic, non-absorbing, and non-allergenic materials
ii. The device should withstand the weight of the patient's forearms, which is approximately 10% of one's body weight [8]. For an American, this means that the device should support an average of 14-20 pounds without breaking, bending, or tipping [9].
iii. No sharp edges. Edges should be rounded to prevent any cuts or scrapes from being incurred by the patient or the medical professional setting up the device.

c. Shelf Life: The device should last for at least 6-8 years.

d. Operating Environment
i. Clean hospital environment. The CT scanning room is cleaned at least once daily with ethanol and disinfectant sprays.
ii. Standard room temperature (20 ± 5ºC)

e. Ergonomics
i. Comfortable for 20 minutes. Device should not induce pain, cramping, or severe discomfort of the patient's arms.
ii. Supports forearms and wrists without discomforting the shoulders
iii. Adjustable to accommodate patients ages 40 to 80.

f. Size
i. Must fit in General Electric's 64-Slice VCT Scanner, which has a 27 in. inner diameter.
ii. Portable such that a nurse or doctor can lift the device and transfer it easily to and from the scanning bed.
iii. Device should be easy to store and should be small enough to fit in a cabinet of the CT scanning room or light and unobtrusive enough to hang up on a common coat hook (should not protrude more than two feet from the wall).

g. Weight
i. The device should weigh less than 30 pounds so that when not in use it can be removed from the scanning bed without inducing excessive stress on the nurse or doctor's arm and back muscles.

2. Production Characteristics
a. Quantity: 1 unit
b. Target Product Cost: under $500

3. Miscellaneous
a. Standards and Specifications
i. If the device moves on to manufacturing and commercial stages, the device must meet hospital cleanliness standards (FDA)
b. Customer/Patient Related Concerns

i. Easy to use and set up. The device should not require a lengthy assembly time, preferably less than 3 minutes.
ii. Minimal training needed. Device should not require anything more complicated than lifting it onto the scanning bed, securing it, and making height and grip angle adjustments.
iii. Reasonable cost. The device should not cost more than $500.
iv. Safe. The device should not hurt or harm the patient or medical professionals in any way.

c. Competition

i. Dr. Jon Keevil's Version 1- Angled grip handle constructed of PVC tubing that provides arm stability during chest CT scans (Fig. 1). The device is attached to the scanning table by a Velcro strap. Pillows are used in conjunction with the device to support the forearms. None of the components are adjustable.

Figure 1. Version 1 as demonstrated by team member.

ii. Dr. Jon Keevil's Version 2- This device is an alteration of the previously mentioned device with a straight handle (Fig. 2).

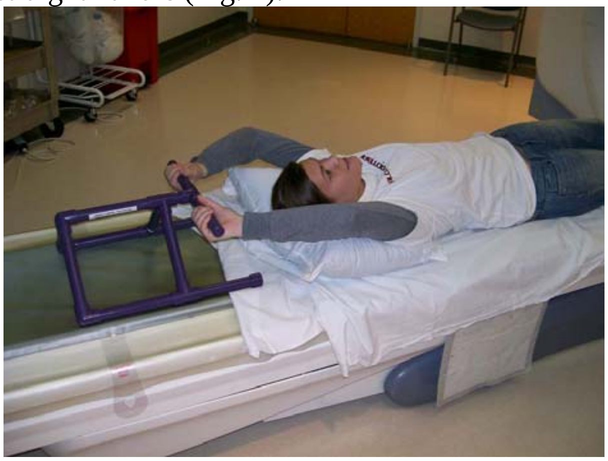

Figure 2. Version 2 as demonstrated by team member.

APPENDIX D - References

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