

Radiologic Arm Support

University of Wisconsin – Madison
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Client:

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Problem Statement

During radiologic procedures to examine the lower spine, patients often lay face-down on a narrow x-ray table for about an hour. In order to facilitate a clear view of the lower spinal region, patients are required to elevate their arms above their head (i.e. so that they are resting their head on their hands). In most individuals, this does not present a problem. However, in patients who have a reduced range of motion in their shoulder joints, this position can be quite uncomfortable. This problem occurs mostly with elderly patients, for whom holding a position such as this for an hour can be painful, if not impossible. In these cases, having removable arm supports that could attach to the sides of the table, upon which patients could comfortably rest their arms, would be advantageous. The goal of this project is to design and build these arm supports, in order to maximize patient comfort.

Literature Search

The design of an arm support for radiologic procedures began with extensive background research. The design team found a variety of supply companies that carried radiologic accessory equipment, including Medsupplier, S & S X-ray Products, Pacific Northwest X-ray, Inc., and Accurate Medical Diagnostics. None of the companies carried removable platforms that could be used as arm supports.

Several products (Appendix B, Current Devices) have been developed for supporting arms during surgical and radiologic procedures. These include an “X-ray support bar” and a “Surgical Arm Support.” These devices were found using online patent search engines at www.delphion.com and the homepage for the United States Patents Office (<http://patents.uspto.gov/>). These products, however, did not satisfy Dr. Tuite because they were not designed for elderly patients lying face-down on radiologic tables.

Background

In addition to this research, information was obtained regarding elderly patients' range of mobility, a primary reason for the development of this product. The Administration of Aging reported that in 1997 more than half of the American elderly population (65 and older) had at least one disability. Amongst this "disabled" population, 26.1% had difficulty carrying out activities of daily life. In addition, over two-thirds of people over age 65 are afflicted with osteoarthritis, the most common form of arthritis (Arthritis, 2002). Symptoms of osteoarthritis include stiffness, pain in the joints, and restricted mobility (Osteoarthritis, 2002). From these statistics, one can clearly see that the elderly population has restricted mobility that has to be addressed when designing medical equipment such as a radiologic arm support.

In order to design an arm support, critical data involving the length and weight of an arm had to be obtained. The design team measured arm lengths of students at UW-Madison and elderly people from Dane County Eldercare (Appendix C, Arm Length Data). The information was analyzed and used to determine the optimal dimensions for the arm support device. Another important test the design team performed was the water displacement of an arm to determine its weight. The arm weight as a percentage of total body weight was also found to help determine an approximate maximum weight that the device must support. From the calculations, the design team concluded that the approximate maximum weight that a platform must be able to support is thirty pounds (Appendix D, Arm Weight).

Design Constraints

After meeting with Dr. Tuite (February 4), a more detailed set of design requirements was established (Appendix A, PDS). As stated before, the arm support device is intended for elderly patients. The device should be removable, adjustable, and

functionally simple. Adjustable lengths would be advantageous to accommodate for varying arm lengths and body sizes. Ideally, the material used for the platforms shouldn't interfere with x-rays in any way. For this reason, most metals should be avoided if possible. The platforms may be built out of plastic or fabric. The material will not have to withstand autoclaving because the platforms will not be used during surgical procedures. However, the material should be durable and capable of withstanding intensive cleaning.

Design Alternatives:

After intensive brainstorming, the team generated multiple design alternatives to maximize the comfort and adjustability of the arm supports. The designs varied in some aspects but were very similar in others. After narrowing down to three distinct design alternatives, the team analyzed and compared the advantages and disadvantages of each.

Design # 1:

The first proposed solution consisted of a plastic platform/arm support emphasizing an adjustable hinge. As seen in Figure 1 below, the hinge of the device would be located just past the edges of the table, where the arm support descends and curves to act as a rest for the patient's arm. Obviously, the most significant advantage of the hinge is its ability to allow the radiologist to adjust the platform to an angle where the patient feels most comfortable. In order to lock the platform at each desired angle, spring-loaded knobs would be used in combination with holes set at specific angles. To switch the platform's angle, one would simply push in the knobs on each side of the hinge and alter the angle. The number of holes on each side of the hinge would determine the number of different angles to which the design could be set (Figure 1). Note, this design would satisfy Dr. Tuite's preference that the platform be easily removable from the radiologic table.

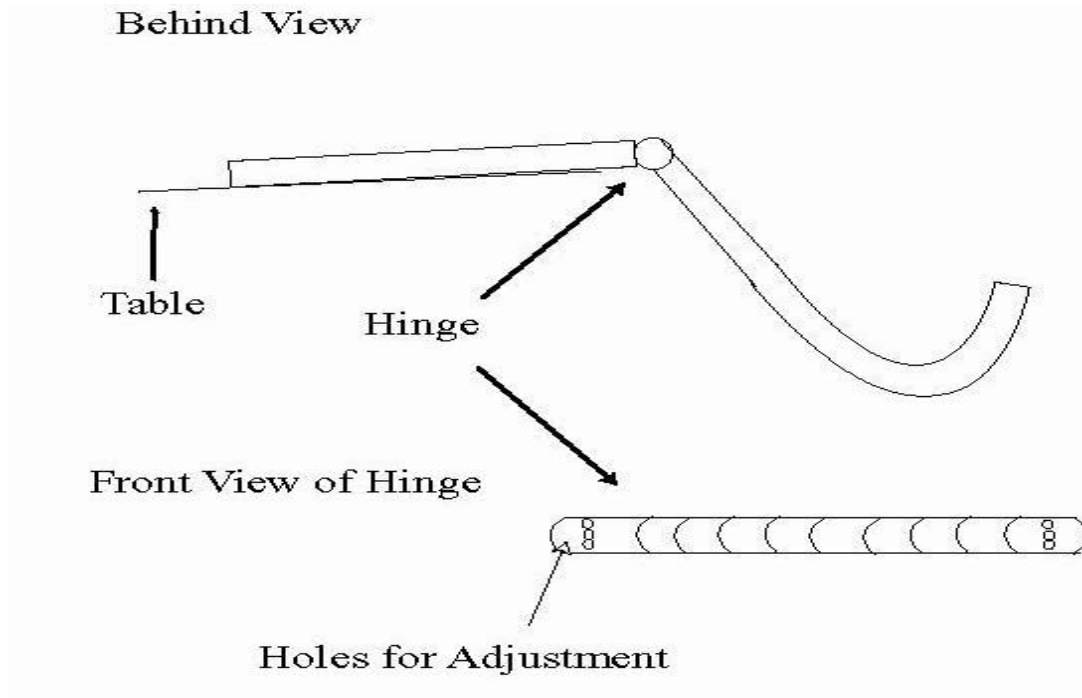
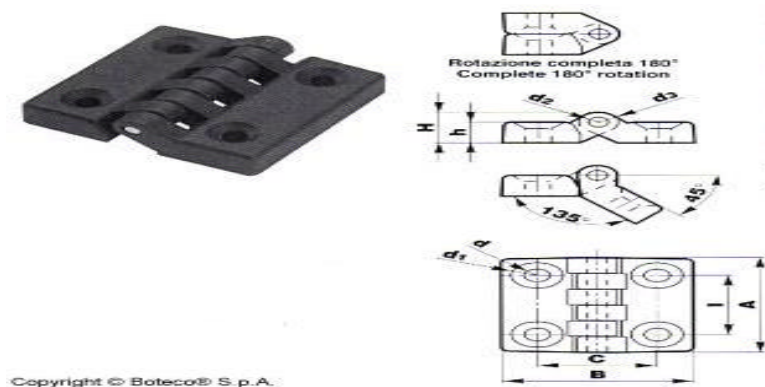


Figure 1: Adjustable Hinge Design

Since this is a radiologic procedure, all of the platform, including the hinge, would be plastic. Plastic, unlike metals, does not interfere with x-rays and would not have to be considered as a potential problem during the procedure. A plastic hinge found online is shown in Figure 2 and is manufactured by a company known as Boteco.



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Figure 2: Plastic Hinge (<http://www.boteco.com>)

The disadvantages of this design are seen with the functional abilities of the device. First of all, the ease of use is not as simple as it might appear. In order to change the hinge angle, the radiologist needs excellent coordination and patience. Coordination is required because while the doctor is using both his hands to push in the spring loaded locks, he must also be able to adjust the arm rest piece to the preferred angle. To further complicate the process, a patient brings a whole new dimension into the procedure. In order for the patient to feel comfortable, the angle changes must be made in a swift but gentle motion. The doctor also must adjust the angle for both arms, a task that could be tedious and time consuming. Finally, the last disadvantage of this design is its inability to directly adjust the length. To compensate, this device should be made for people with longer arms so that padding, such as towels, could be utilized to accommodate those with short arms. The padding would be placed in the cupped region of the arm support so that a person with a shorter arm could be comfortable using this device.

Design # 2:

The size and shape of the second design is essentially the same as the first. This device, like the first, would be made completely of plastic and would have spring loaded knobs. This proposed design, however, dealt with a method to adjust the length of the platform rather than the angle and thus compensated for patients with varying arm lengths. As a response to this variant, the length between a person's armpit and his elbow would serve as a rough estimate of the distance from the table to the support.

The significant features of this proposed solution are the movable slab and mounting strips (shown in Figure 3). The movable slab adjusts by sliding between the two mounting strips and locking in place with spring loaded knobs located on both sides. To operate the device, the knob on each mounting strip would have to be pressed in while

moving the slab to the desired position. In figure 3, one can see that an open hole is needed above the slab to allow it to move. The primary advantages of this design are the adjustable length and its ability to be removed from the table.

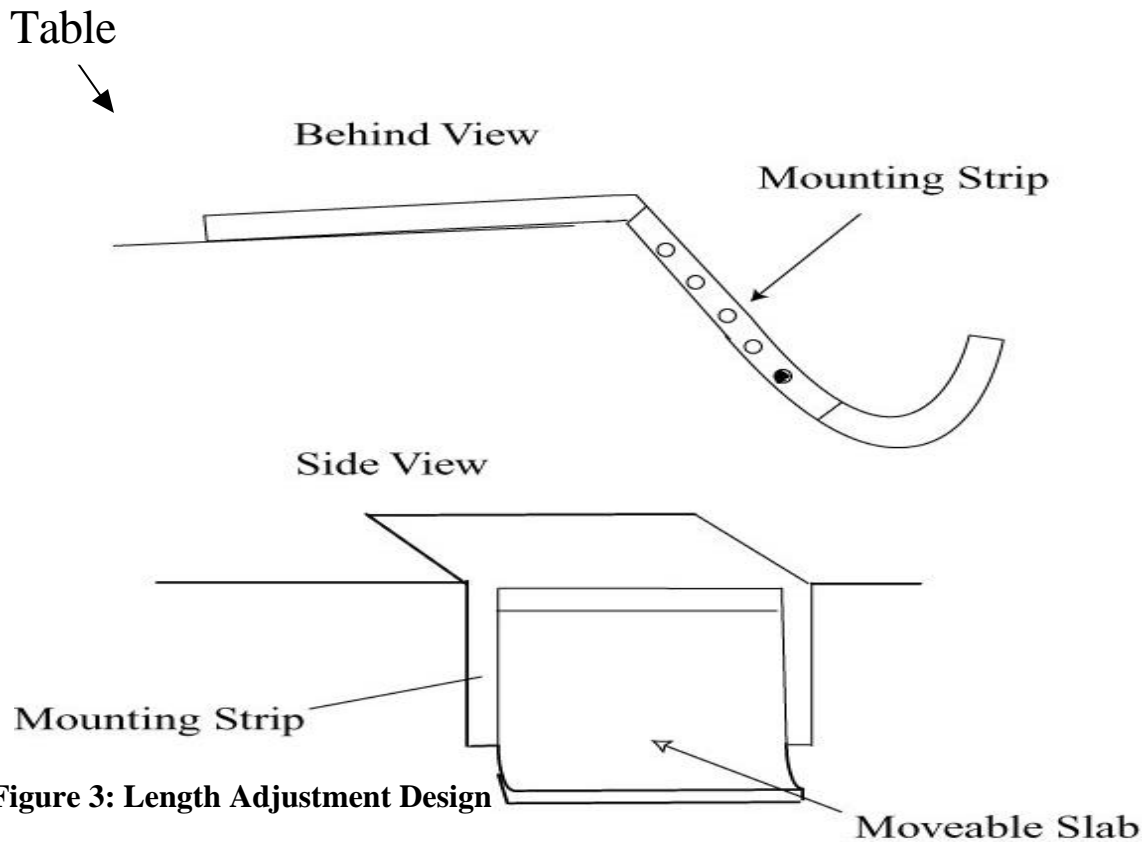


Figure 3: Length Adjustment Design

Table or disadvantages, this design could cause several complications. Open Hole

This product may be hard to adjust while a patient is lying down on the radiologic table. A new issue arises with moving parts. When parts move, the durability and service life dramatically decrease because parts could break and require replacements. Finally, this bulky-shaped design would be hard to store in a compact area.

Design # 3: Chosen Design

The design concept that we have settled on involves a system anchored in place via a plastic piece fitted between the x-ray table and the pad covering it (Figure 4).

When the patient lies on the pad, his weight will anchor the system in place. At the end of this plastic piece, a small area will be cut out, such that a small "rod" (parallel to the

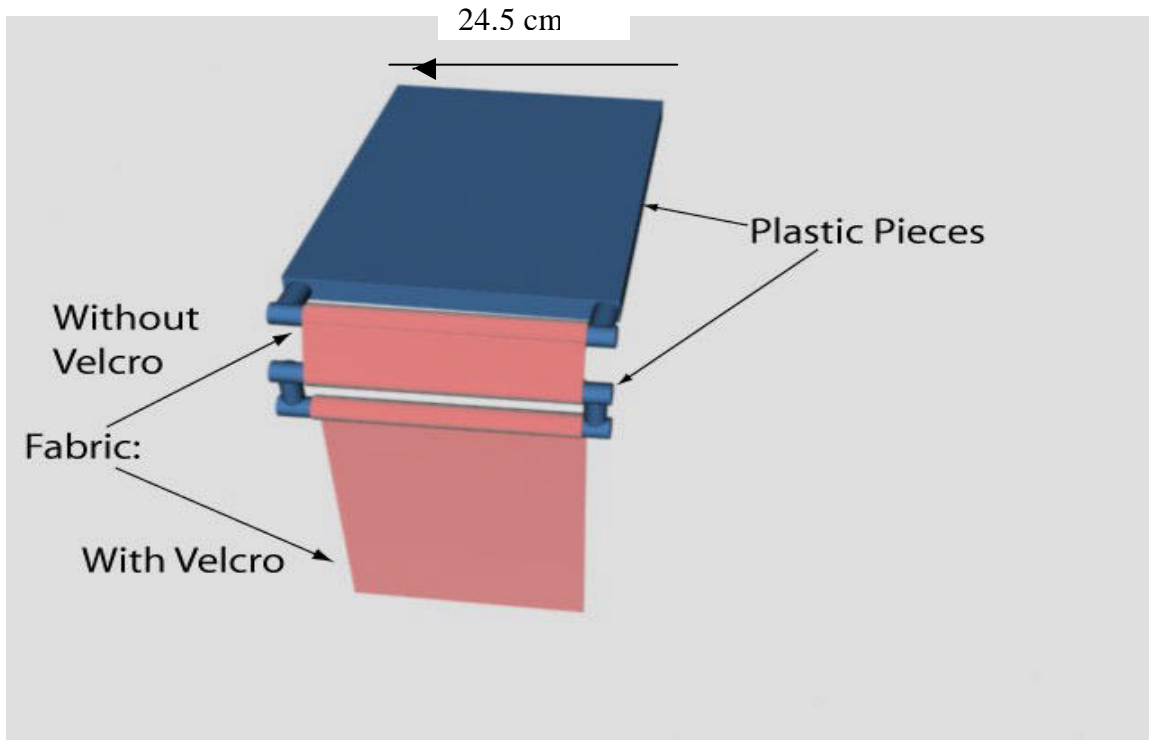


Figure 4: 3D Image of Chosen Design

edge of the table) will be formed. Around this rod, a piece of fabric will be sewn. The fabric used will be fluid-resistant. This first piece of fabric will serve to connect the plastic slab that is under the patient to another plastic piece. The function of this second plastic piece will be to act as a “slot” for a second piece of fabric to pass through. Along this second piece of fabric, Velcro will be attached. A portion of the front side will be covered with “unsticky” Velcro, and a portion of the back side will be covered with “sticky” Velcro (Figure 5). To support a patient’s arm, the piece of fabric with the Velcro will be wrapped around the patient’s forearm and then back through the slot formed by the 2nd plastic piece. After the fabric is through this slot, the two types of Velcro will be secured together to hold the patient’s arm in place. At the second meeting

(February 15), Dr. Tuite expressed his approval of this concept. For dimensions of each component of the system, see Figures 5 and 6.

Dimensions of Fabric Pieces

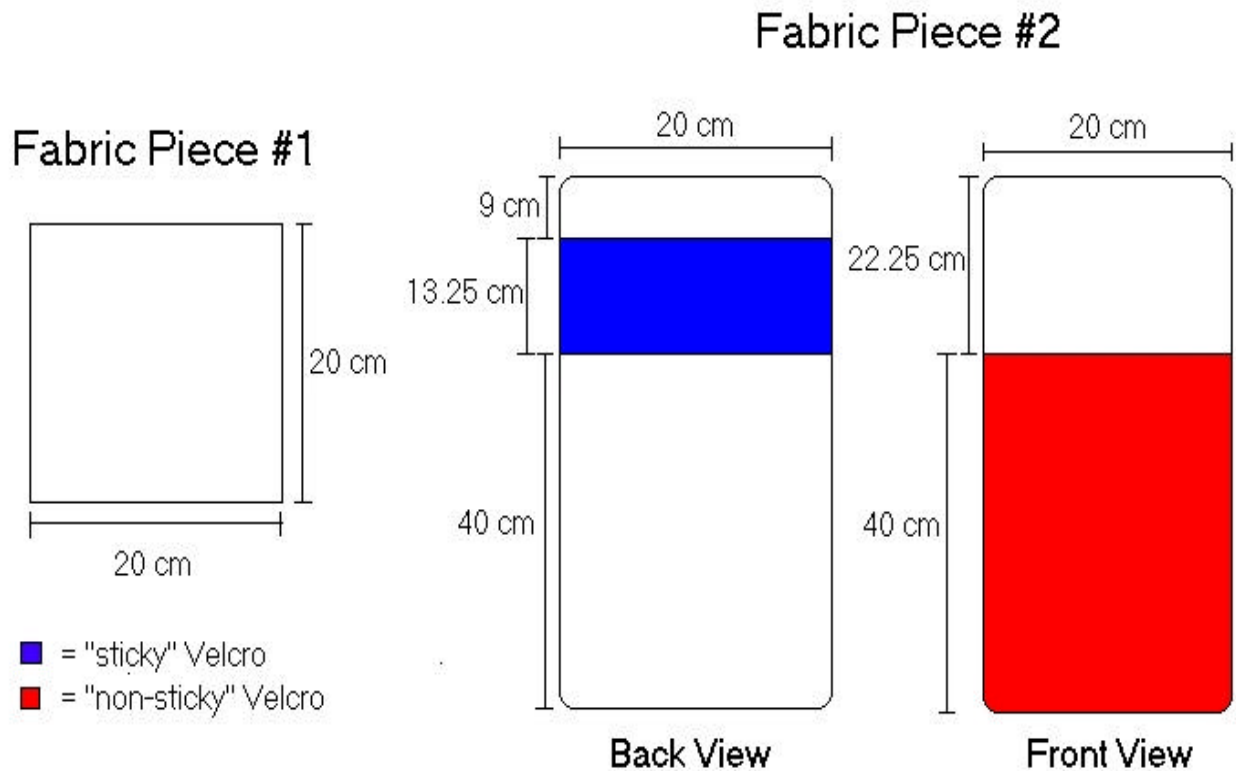


Figure 5: The dimensions of fabric pieces, which were calculated based on the arm length data.

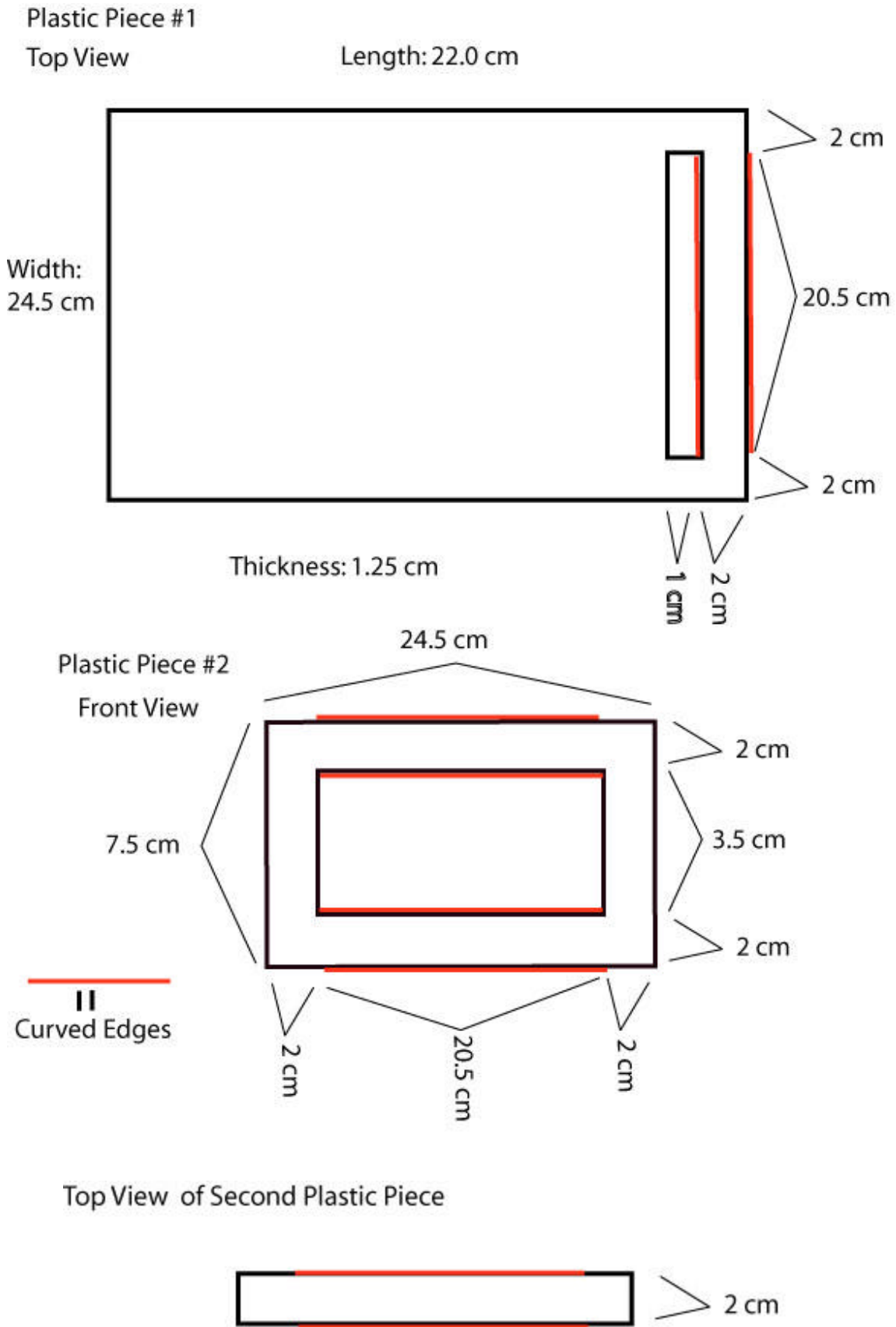


Figure 6: Dimensions of plastic pieces for chosen design

Advantages of Chosen Design

There are multiple reasons why the team has chosen to pursue this particular design idea. First of all, the design will maximize comfort for the patient. Fabric, which is relatively soft and pliable, will be significantly more comfortable than a hard, unyielding plastic. It will have much more of an ability to conform to the size and shape of each patient's forearm. With plastic, this would not occur. Second, the design the team has chosen eliminates the complication of trying to build a device that is length-adjustable. The design is adjustable by its very nature. Had the team chosen to use a "J-support", anchored at a set point on the device, it would have only fit a specific arm length. Making it adjustable to fit other arm lengths would have been relatively complicated. The design provides a much simpler, more practical solution to this dilemma by simply wrapping the fabric around the patient's forearm. In other words, the length of the patient's arm determines the length at which the device is set. This allows patient's of all sizes to be comfortably accommodated. Third, by choosing a device made strictly of plastic and fabric, any concerns about using materials that will interfere with x-rays are eliminated. The materials being used will not affect the image being taken. Fourth, the chosen design conforms to whatever angle the patient's arm naturally hangs at. The first fabric piece acts as a joint, allowing the system to be rotated about an axis parallel to the edge of the examination table. Lastly, this system is very easy to use. It requires no adjustment; the fabric is simply wrapped around the patient's arm, through the slot, and secured.

Potential Problems

As with any product, problems may arise. Many of the problems with this product will deal with the plastic, Velcro, or fabric material. As for the plastic, there could be problems with the durability of the rod. In order to make sure the rod does not

break off, the slit made in the plastic must not be too close to the end or sides of the plastic and the rod itself must be of an adequate thickness. Another problem is that the sticky part of the Velcro may lose its sticky quality with time. To prolong this from happening, a large Velcro strip providing an adequate area of possible attachment is used. Another component that keeps the Velcro in good condition is the second plastic piece, as seen in the final design choice (Figure 4). This piece will reduce the stress on the Velcro by providing a larger gap that it can pass through. Furthermore, since the Velcro and fabric are sewn together, there is a possibility of them coming apart. Therefore, as a preventive measure, the fabric will be double-stitched. Finally, in case of fluid spills, the materials used will be waterproof.

A patient may have the Velcro around his arm for about an hour. Since Velcro is not a material that breathes well, the patient's arm may get hot or sweaty. In an attempt to avoid this, the team considered adding mesh segments down the length of the Velcro band. The mesh segments, however, would be flimsy and when the Velcro band is wrapped around the patient's arm, they may overlap with a non-mesh portion and therefore be ineffective. Another issue neglected in the product is padding. The patient's arm may rest uncomfortably against the side of the x-ray table, but since the table is quite narrow this will probably only occur with a small number of patients. To combat this, the doctor can simply wrap a towel around the patient's arm to add comfort. Unfortunately, it would be too bulky to add permanent padding to the final chosen design.

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Product Design Specifications (PDS)

March 9, 2002

Platform for arm support during radiologic procedures

Team Members: Matt Harris, Luke Harris, Brandon Verdoorn, and Andrea Rozmenoski

Client: Michael Tuite

Advisor: Paul Thompson

Function:

The designed platforms will offer maximum comfort to patients, especially older people, while they undergo radiologic procedures involving the spine. By supporting their arms during these procedures these platforms will allow patients to relax and not be in pain. Currently, patients must lie on their stomach and hold their arms outstretched to allow access of the x-rays. In older individuals, however, this becomes tiresome and painful during the exam.

Client Requirements:

- Develop platforms so a patient's arms rest on the sides of a table – don't want them to dangle
- Problem – older people have more difficulties
- Younger people probably won't need the platforms – more flexible and limber
- Platforms should be removable
- Procedure length – normally about 1 hour
- Platforms don't need to be sterilized
- X-rays should travel through the platforms
- Adjustable angles and lengths may be beneficial
- Should be able to withstand spills and cleaning using solvents such as alcohol

Design Requirements:

Must be small enough to fit within the circular motion (360 degree rotation) of the radiologic device that moves around the patient.

1. Physical and Operational Characteristics:

- a. Performance Requirements:* The devices must allow the patient to relax their arms during the radiologic procedure. The platforms should be capable of being used multiple times throughout the day and they should be removable.

- b. *Safety:* The platforms should ONLY be used for radiologic procedures. There should be no sharp edges on the devices to avoid any harm to the patients.
- c. *Accuracy and Reliability:* The devices must be sturdy and be able to hold up to approximately 30 pounds - the maximum weight of a patient's arm (patients are 300 pounds or less due to limitations of the radiologic table).
- d. *Life in Service:* 10 to 15 years (the device should last for many years if taken care of appropriately). In most cases, the device will last until dropped, mishandled, or until the material (Velcro, fabric, or plastic) wears out.
- e. *Shelf Life:*
 - Store in cabinet in x-ray room (no extreme temps, pressures, humidities, etc...)
 - Shelf Life of product
 - Plastic: unlimited
 - Metals (if used): unlimited
 - Velcro (if used): 10-15 years (until Velcro is no longer functioning)
- f. *Operating Environment:*
 - Temperature, pressure, humidity all in typical "room" ranges
 - Exposure to dust from the air
 - Exposure to x-rays
 - Handled by physicians/technicians and possibly patients
 - Possible shock loading situations (i.e. – patient loses balance while getting onto table and uses device to catch themselves, placing patient's full weight on the device)
 - Ability to support a maximum arm weight of 30 pounds (Appendix D, arm weight)
- g. *Ergonomics:*
 - Comfortable for the patient
 - Physician friendly
 - Easily adjustable (i.e. – moving parts, if any, not too small; not too much force required for adjustment)
 - Easily removable
- h. *Size:*
 - Plastic portion that goes under table pad no more than 20 cm long
 - Adjustable length
 - Adjustable angle (not necessary)
 - From 20 to 70 degrees
 - Short enough so as to not interfere with x-ray source and/or cathode tube
 - Plastic thickness of about 5 mm
 - Table is slightly concave (about 2-3 degrees)

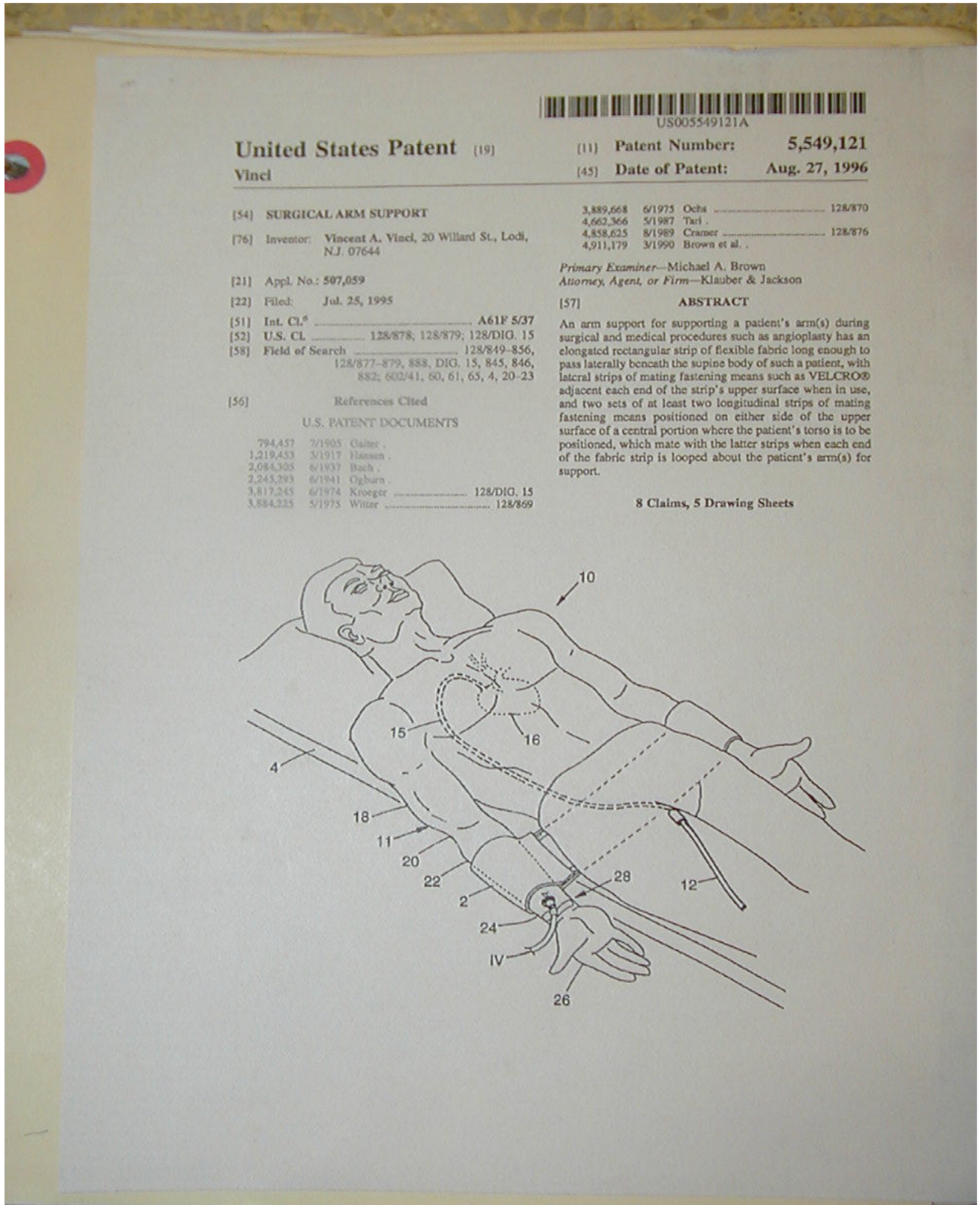
- i. *Weight*: The platforms should be light enough so a doctor can easily remove them from their stored location and position them underneath the patients' arms. Each platform should not exceed 10 pounds.
- j. *Materials*: Ideally, the material used for the platforms shouldn't interfere with x-rays in any way. For this reason, most metals should be avoided if possible. The platforms may be built out of plastic or maybe some kind of fabric. The material will not have to withstand autoclaving procedures because the platforms will not be used during surgeries.
- k. *Aesthetics, Appearance, and Finish*: Should be professional looking, with no jagged edges or surfaces that could catch clothing or cut the skin. The color is irrelevant for the purpose of the device.

2. Production Characteristics:

- a. *Quantity*: Two working prototypes (one for each arm).
- b. *Target Product Cost*: The total cost has been estimated at \$150 for each platform.

3. Miscellaneous :

- a. *Standards and Specifications*: No special regulations have to be met.
- b. *Customer*: Intended use is for people over 55. Must be comfortable (a.k.a. no sharp edges, padding, and angle/length fitting), adjustable, removable, and capable of withstanding pressure from the arm.
- c. *Patient-related concerns*: The platform will not be sterilized; however, it will be reusable. It must be easy to use and adjustable to fit arm appropriately.
- d. *Competition*: Through several patent searches, one product was found that may be similar to the device desired by the client. This product is United States Patent number 5,549,121 and is titled "Surgical Arm Support."



United States Patent [19]

Doughty

[11] 4,223,862

[45] Sep. 23, 1980

[54] PATIENT SUPPORT APPARATUS

[76] Inventor: Val J. Doughty, P.O. Box 26075,
Tempe, Ariz. 85282

[21] Appl. No.: 961,984

[22] Filed: Nov. 20, 1978

[51] Int. Cl.³ A47B 96/06

[52] U.S. Cl. 248/222.3; 211/105.1;
403/263

[58] Field of Search 248/222.3, 222.2, 222.4,
248/223.1, 223.2, 223.4, 224.1, 224.2, 224.4,
221.3, 118.1; 211/103, 105.1; 250/491; 403/263,
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Primary Examiner—J. Franklin Foss
Attorney, Agent, or Firm—LaValle D. Ptak

[57] ABSTRACT

A patient support apparatus for use with medical X-ray equipment to provide a convenient arm support for patients during the time medical X-rays are being taken comprises an elongated rectangular anchor member mounted on the wall adjacent the medical X-ray apparatus. The anchor member has a number of vertically aligned apertures formed in it for receiving a horizontally extending arm support bar. The support bar is dimensioned to fit snugly into the various apertures and can be removed readily from any one of such apertures for re-insertion into another aperture. This permits adjustment of the height of the support bar relative to the X-ray equipment to accommodate patients of different heights and to adapt the support bar for use with standing patients or patients who are sitting on an examination table adjacent the X-ray apparatus.

9 Claims, 6 Drawing Figures



Appendix C

Arm Length Data and Analysis

Male (M) or Female (F)	Armpit to Elbow	Elbow to wrist	Forearm Circumference - widest part
Students and Advisors	(cm)	(cm)	(cm)
M	32.8	27.1	28.8
M	31.3	27.6	30.2
M	32.5	26.9	29.2
M	26.9	24.5	28.5
F	32.0	26.3	22.5
F	25.4	26.7	27.9
F	25.4	24.1	24.1
F	22.9	25.4	22.9
F	24.1	25.4	24.1
F	21.6	24.1	24.1
F	22.9	24.1	25.4
F	22.9	24.1	25.4
M	25.4	25.4	27.9
M	29.5	26.8	27.1
M	30.5	27.9	27.3
M	30.5	26.0	26.0
M	29.2	27.3	27.9
M	31.1	26.0	26.7
Elderly			
F	19.1	26.7	26.3
F	20.9	25.1	24.1
F	21.6	25.4	31.8
F	21.6	23.5	26.7
F	22.9	27.9	26.0
M	21.6	24.1	26.0
M	21.6	27.9	27.9
F	22.9	24.1	36.8
F	19.1	21.6	29.2

Male (M) or Female (F)	Armpit to Elbow	Elbow to wrist	Forearm Circumference - widest part
	(cm)	(cm)	(cm)
Students and Advisors Standard deviation	3.826144154	1.296513676	2.249763967
Elderly standard dev	1.383032096	2.095298971	3.876997693
Overall standard dev	4.41198833	1.603797132	2.956088892
Overall Maximum	32.8	27.9	36.8
Overall Minimum	19.1	21.6	22.5

AVERAGE	27.6	25.9	26.4
Elderly AVERAGE	21.3	25.1	28.3
Overall AVERAGE	25.5	25.6	27.1
Range for 68% of this population (within 1 deviation of mean)	21.08801167 – 29.91198833	23.996202868 - 27.203797132	24.143911108 - 30.056088892
Range for 95% of this population (within 2 deviations of mean)	16.67602334 – 34.32397666	22.392405736 - 28.807594264	21.187822216 - 33.012177784
Range for 99% of this population (within 3 deviations or mean)	12.26403501 – 38.73596499	20.788608604 - 30.411391396	18.231733324 - 35.968266676

*** Using this data, the team was able to design a radiologic arm support with appropriate dimensions. Most, if not all, patients will be able to use the product.**

Appendix D

Experiment: Measuring the weight of an arm using water displacement

Purpose: To determine the weight of someone's arm. (Specifically Luke Harris's arm)

Equipment: Two water buckets
One smaller bucket (pail to insert arm into)
One larger bucket (to catch the water that's displaced)
500 mL beaker (or another volume measuring device)

Theory: Density of a person's arm is approximately 1.05 kg/L (very close to the density of water – 1.00 kg/L)

Density equal Mass/Volume

1 kg = 2.2 pounds

Procedure:

1. Fill smaller bucket completely with water
2. Place smaller bucket full with water into larger bucket (be careful to not spill any water!)
3. Submerge arm into smaller bucket to displace the water
 - CAUTION: Move arm slowly into the bucket to avoid spilling
4. Measure the volume of the water using a 500 mL beaker that is now in the larger bucket.

Data

Volume of water displaced by Luke's arm = 4.350 L

Calculations

Mass = Density x Volume

Mass = (1.05 kg/L) x (4.350 L) = 4.5675 kg

Weight = 4.5675 kg x 2.2 lb/kg = 10.05 lb

Arm weight as a percentage of total body weight

Luke's weight = 180 lb
(10.5 lb/180 lb) x 100 = 5.58% = **Arm weight as a percentage of total body weight**

* **Result Analysis:** The maximum weight that a radiologic table can hold is a 300 lb person. Given this and the fact that the percentage of arm weight will most likely never exceed 10%, the approximate maximum weight that an arm support device would have to hold is: $10\% \times 300 \text{ lb} = 30 \text{ pounds}$