Radiologic Arm Support

University of Wisconsin – Madison
College of Engineering
BME 201
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Abstract

To x-ray the lower spine during radiologic procedures, patients must lie face down on a table with their arms elevated above their heads. Seeing that this arm position can be painful or even impossible for elderly patients, we designed a product that would comfortably support an elderly patient's arms, while maintaining the integrity of the X-ray image. We considered multiple designs and chose a device consisting of plastic and fabric with Velcro© to secure the patient's arms. The prototype was built and tested. Testing included obtaining evaluations from multiple users (qualitative) and determining how much weight the device could support (quantitative).

Problem Statement

During radiologic procedures to examine the lower spine, patients are often required to lay facedown on a narrow x-ray table for over 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. However, none of these companies carried removable platforms that could be used as arm supports.

Several products have been developed for supporting arms during surgical and radiologic procedures. These include an "X-ray support bar" and a "Surgical Arm Support" (Appendix B). These devices were found using online patent search engines at www.delphion.com (3) and the homepage for the United States Patents Office (8). These products, however, did not satisfy Dr. Tuite because they were not designed for elderly patients lying facedown 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 (1) reported that in 1997 more than half of the American elderly population (65 and older) had at least one disability. Among 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 (4). Symptoms of osteoarthritis include stiffness, pain in the joints, and restricted mobility (5). 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 and advisors at UW-Madison and elderly people from Dane County Eldercare (Appendix C). 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 16.74 pounds (Appendix D).

Design Constraints

After meeting with Dr. Tuite (6), a more detailed set of design requirements was established (Appendix A). 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 varying arm lengths and body sizes. Ideally, the material used for the platforms should not interfere with x-rays. For this reason, most metals should be avoided. In addition, the device will not have to withstand autoclaving because the platforms will not be used during surgical procedures and therefore are not required to be sterile. However, the material should be durable and capable of withstanding intensive cleaning. Considering these criteria, plastic, fabric, and x-ray transparent metals would be the optimal materials to use.

Design Alternatives

After intensive brainstorming, the team generated multiple design alternatives that would provide maximum comfort and adjustability. These designs varied in some aspects but were similar in others. After narrowing down to three distinct design alternatives, the team analyzed and compared the advantages and disadvantages of each.

<u>Design # 1:</u>

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).

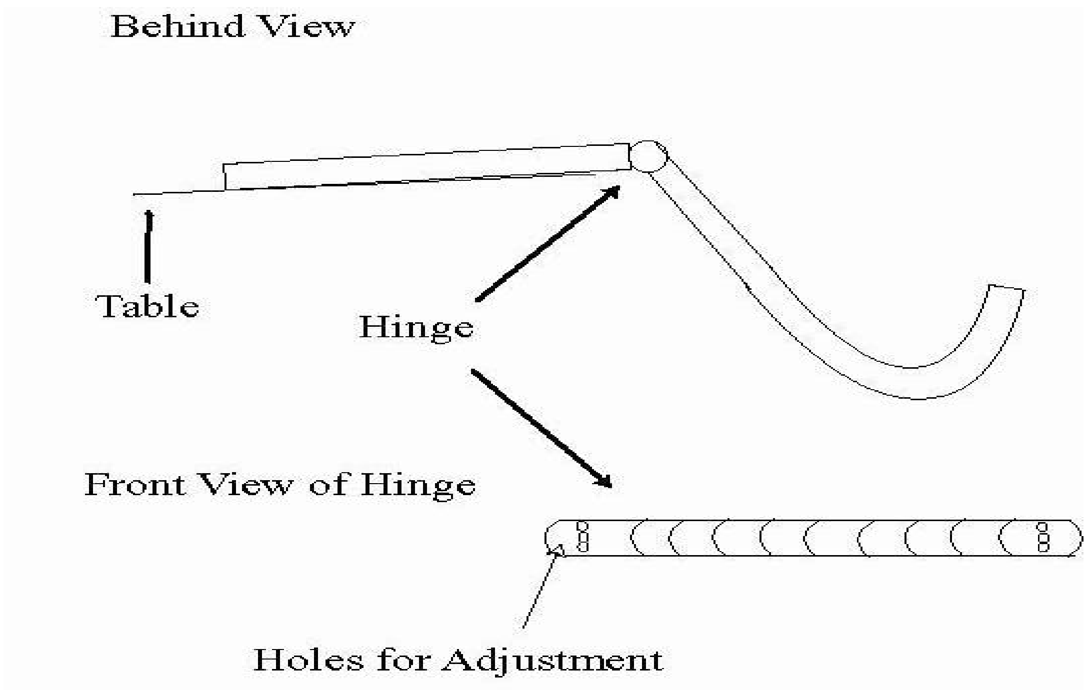


Figure 1: Adjustable Hinge Design

Note that this design would satisfy Dr. Tuite's preference that the platform be easily removable from the radiologic table. In addition, the platform and the hinge would be made of plastic, which, 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 (4).

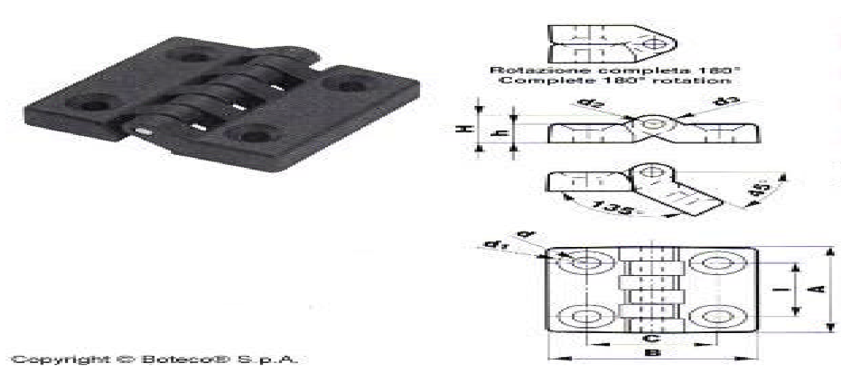


Figure 2: Plastic Hinge (http://www.boteco.com)

The disadvantages of this design are seen in the functional abilities of the device. First of all, ease of use could present a problem. 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. To maximize patient comfort, 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 length of this device can not be directly. To compensate, it 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 it.

<u>Design # 2:</u>

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. 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 (Figure 3). The slab moves by sliding between the two mounting stripsm and is locked in place with spring-loaded knobs located on each side. To operate the device, the knob on each mounting strip would have to be pressed in while moving the slab to the desired position. 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.

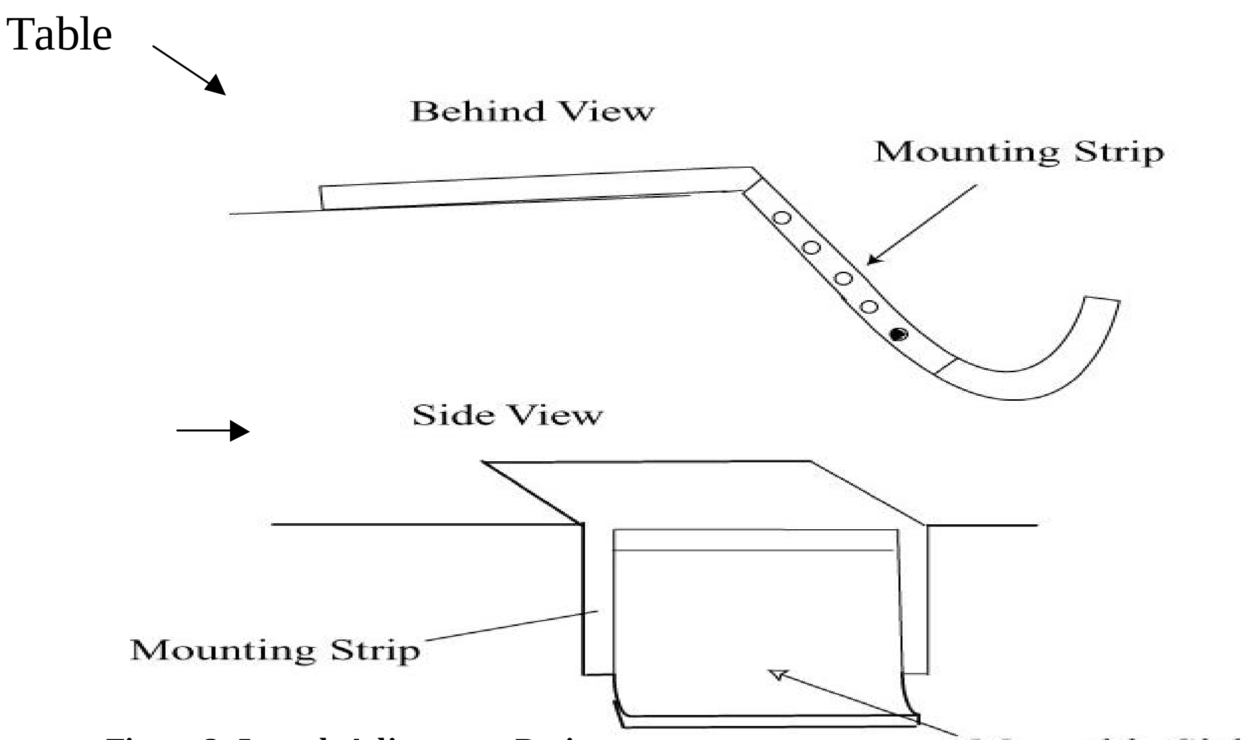


Figure 3: Length Adjustment Design

Table

Open Hole

As for disadvantages, this design could cause several complicati

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

<u>Design # 3: Chosen Design</u>

The design concept that we was 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 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

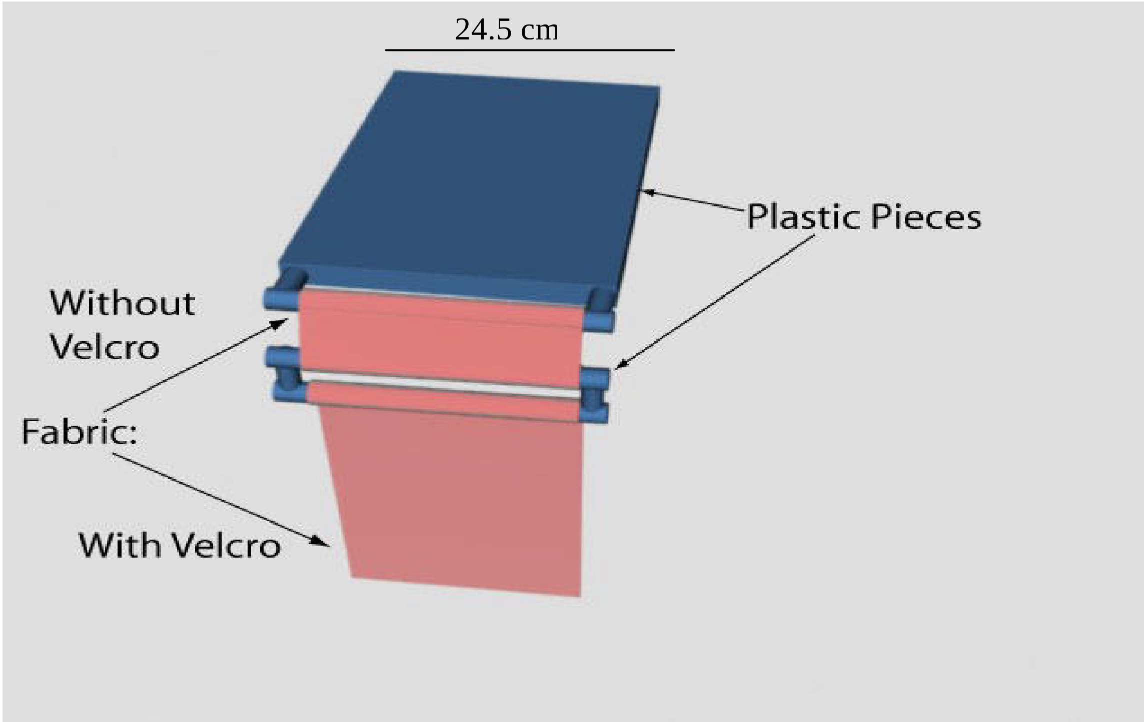


Figure 4: 3D Image of Chosen Design

this second piece of fabric, Velcro© will be attached. A portion of the front side will be covered with loop Velcro©, and a portion of the backside will be covered with hook 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 second 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 (7), Dr. Tuite expressed his approval of this concept. For dimensions of each component of the system, see Figures 5 and 6.

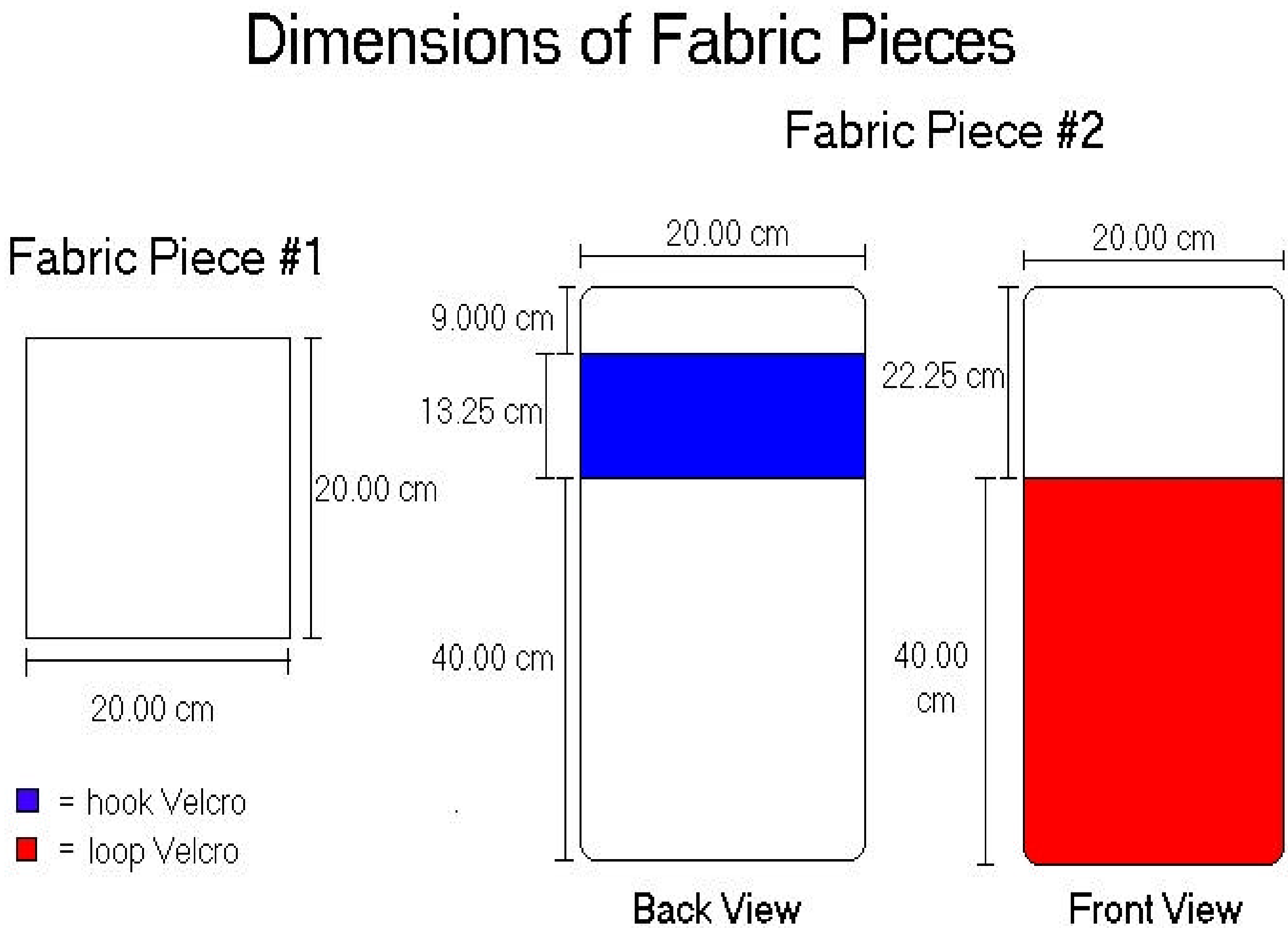
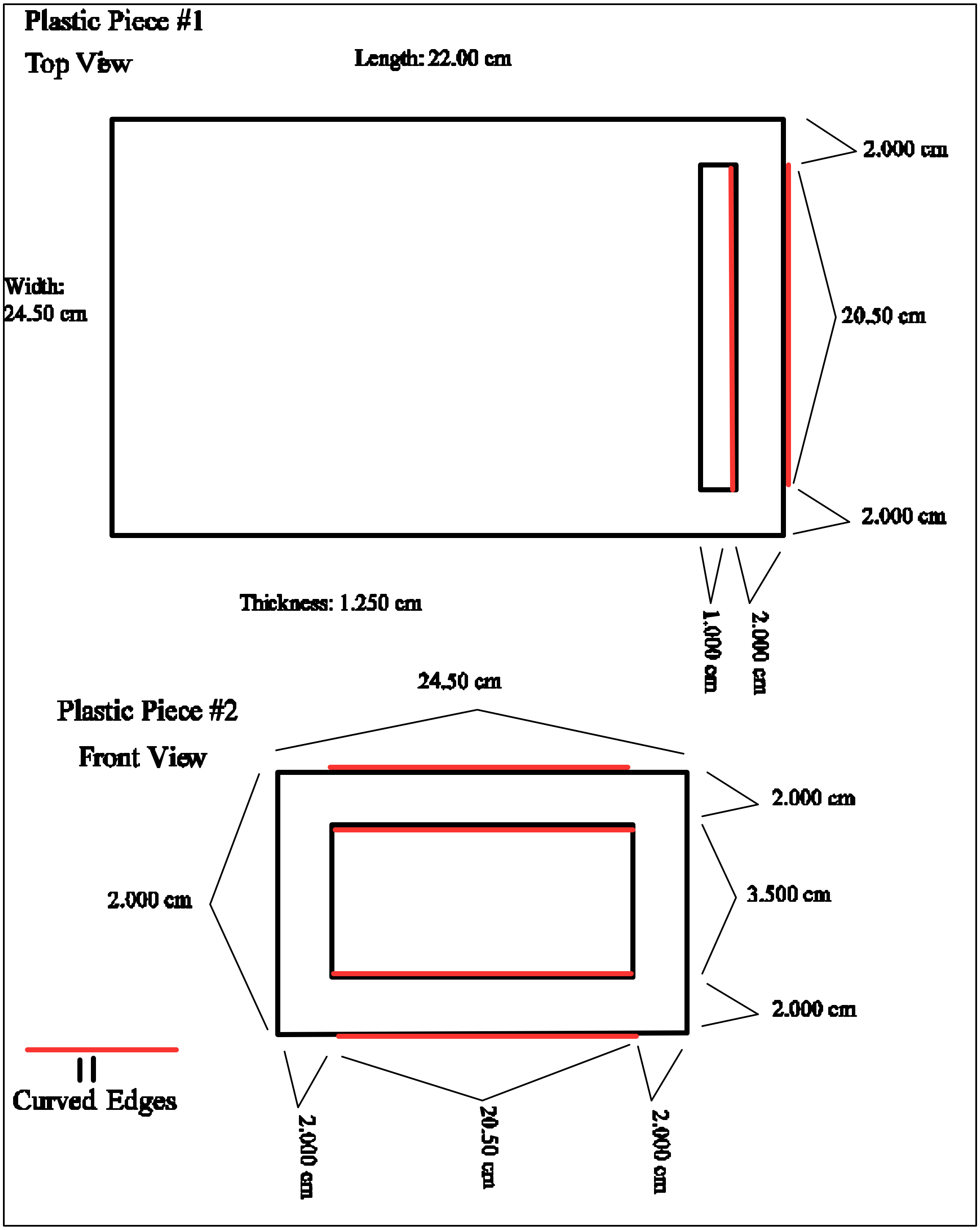


Figure 5: The dimensions of fabric pieces, which were calculated based on the arm length data (not to scale).



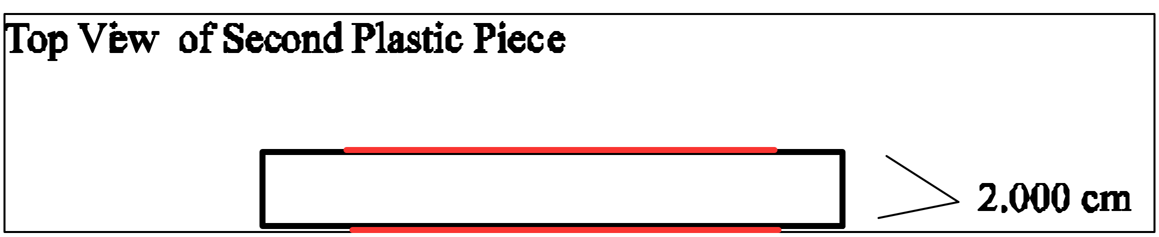


Figure 6: Dimensions of plastic pieces for chosen design (not to scale)

Advantages of Chosen Design

There are multiple reasons why the team has chosen to pursue this particular design idea. First of all, it 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 chosen 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 patients of all sizes to be comfortably accommodated (Figure 8). Third, by choosing a device made strictly of plastic and fabric, any concerns regarding x-ray interference are eliminated. The materials being used will not affect the image being taken. Fourth, the chosen design conforms to the angle at which the patient's arm naturally hangs. 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. As for the plastic, there could be problems with the durability of the rod. In order to make sure this part 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 Velcro© may lose its adhering ability over time. To delay this from happening, a large Velcro© strip that provides a large attachment area is used to distribute the stress on the Velcro©. 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, to avoid damage from fluid spills, the materials used will be waterproof.

A patient may have the Velcro© around his arm for over 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. For this reason, the team chose not to incorporate them. 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.

Construction of Prototype

Using the drawings and dimensions (Figures 4-6) as a guide, a prototype was built. The design team decided to build only one arm support in order to save money and hopefully receive feedback from Dr. Tuite. The first step in the development of the prototype was having the mechanical engineering shop cut plastic sheets according to the design specifications. Specifically, the pieces were built out of PVC, which is a strong and extremely durable plastic. The PVC pieces alone cost only $25. However, the six hours of labor needed to round specified corners of the plastic pieces cost an additional $300. The second step in building the prototype involved buying fabric and Velcro©. The fabric needed to be strong, resilient, and capable of withstanding extensive cleaning. For these reasons, the engineers bought outdoor furniture fabric from outdoorfabrics.com. One square yard of black fabric cost $24.69. This amount of fabric will be sufficient to build two arm supports. The second device will be built after the design team receives feedback from Dr. Tuite about the first prototype. The Velcro© came in a long two-inch wide strip and was purchased at a local fabric store for $37.39. Finally, the last step in the construction of the prototype was to take the plastic pieces, Velcro©, and fabric to a seamstress. The seamstress sewed the fabric and Velcro© according to Figure 5. The cost of the sewing was $20.00. Overall, the prototype (Figure 7) cost $407.08.

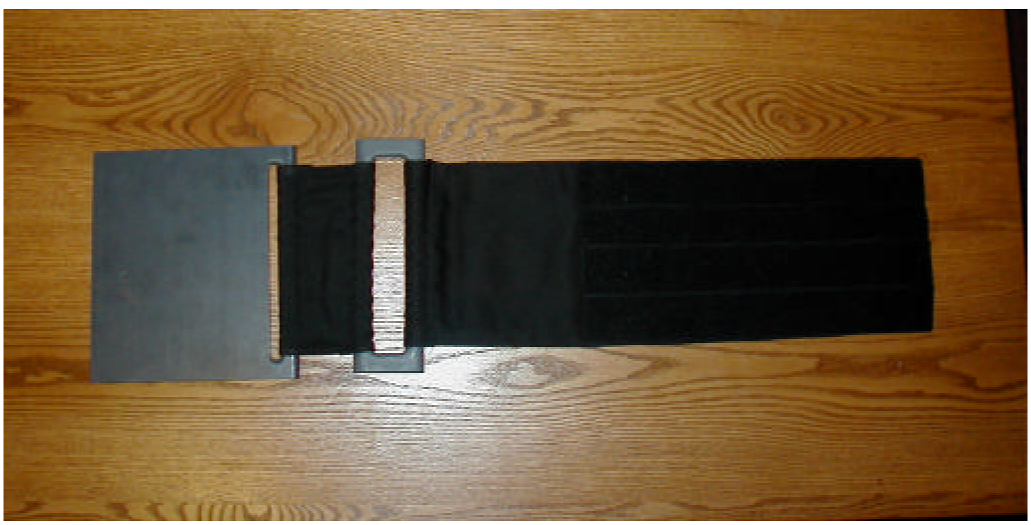


Figure 7: Image of Constructed Prototype

Qualitative Testing

Once the prototype was completed, the team of engineers performed two tests. One test was qualitative and the other was quantitative. The qualitative test was developed to determine the comfort level and "ease of use" of the device. The test was performed as follows. First, two random students were selected. One student became the patient and the other was the doctor. The engineers explained their project and told the students how the device was used. Then, using the table that was already set up, the "doctor-student" helped the "patient-student" use the arm support. A picture of a patient-student using the device can be seen in Figure 8 below. The "patient-student" was then asked how comfortable the device was based on a one to ten ranking system,

Figure 8: A student-patient using the constructed prototype

where ten was the best. Finally, using the same ranking system, the "doctor-student" was asked how easy the device was to use. The results indicated that the comfort level for the prototype averaged a rating of 8.95, while "ease of use" was given an average rating of 7.90 (Appendix E). Although these numbers are good, these results are not conclusive due to the limited number of trials. The "patients" were also not representative of the elderly population, for whom this product is intended. The most beneficial results from this test came from observing the problems that arose while the students were using the platform. For example, bulky sweatshirts seemed to cause many problems for the "doctors" when they tried to adjust the device. Another difficulty arose because the platform could slide on the table. One “patient-student” pointed out that her hand hung too far below her elbow, causing blood to pool into her fingers. In a clinical setting, this could cause the patients arm to fall asleep. These issues are important to the design team because they indicated how the design could be improved in the future.

Quantitative Testing

In addition to the qualitative testing that was performed, a quantitative test was administered as well. In accordance with the group’s earlier test that determined arm weight as a percentage of body weight (Appendix D), a range of weights that the prototype should be capable of supporting was determined. The maximum weight that the radiologic table can support is 300 pounds, which corresponds to a maximum arm weight of around 16.74 pounds (5.58% x 300). The team decided on a safety factor of 2.0, meaning that it should be certain that the product can hold 2.0 times the maximum weight it will ever have to hold during clinical use. In this case, this meant that the prototype should hold at least 33.48 pounds. This corresponds to a person weighing 600 pounds. The team tested to see if the prototype could support this much weight. This was accomplished by hanging dumbbells where an arm would typically rest. Starting with a 5-pound dumbbell, testing progressed in 5-pound increments up to 35 pounds (Figure 9). Each test was approximately 5 minutes in length.

Figure 9: Quantitative Testing with a 25 lb dumbbell

Patent Process

As an addition to the conventional requirements for the project, the design team has decided to pursue a patent for its product. The process of applying for a patent should be a valuable one, regardless of whether or not it turns out to be successful. It provides great first-hand knowledge that could prove valuable in future endeavors as a biomedical engineer.

The process the team has gone and will go through consists of the following. It was determined that the invention would be disclosed to the Wisconsin Alumni Research Foundation (WARF), who would then assist with the process of applying for a patent. This process began with the completion of the Invention Disclosure Report (IDR) form. This form, which asks for general information about the invention, such as date of conception and date that the invention was first shown to work, along with information about members of the design team, has been submitted to WARF. The team is currently waiting to hear back from them. An intellectual property manager from WARF will contact the design team in the near future and set up a meeting to further discuss the product. At this point, the WARF representative will draft a paper presenting the invention, which will be presented to a committee at WARF, who will decide whether or not to further pursue this invention (i.e. apply for a patent). The design team hopes to continue with this ongoing process during the remainder of the current semester and over the summer.

Conclusion

Ethical Issues

Apparent in this project are several ethical issues that should be carefully considered. First of all, the device should be designed so that everyone can use it, including people with limited movement or deformities. The intent of the design team was to develop a product to accommodate a wide range of people. The range of arm sizes that can be supported by the product is sufficient to serve the majority of potential patients.

Another ethical issue became apparent in the patent process. It may not be ethical to patent a device to be used for medical purposes. If multiple companies can manufacture a product, it will most likely result in more efficient production and lower costs. A patent may limit this from happening. With a patent for the design, the price of the product could be sufficiently higher since there is no competition. A patent also prevents other people from making similar products, even if they could make a more efficient design. By getting a patent, the design team is forfeiting its marketing rights to WARF and, therefore, will not have a say in the market price. So, the real question may be whether or not WARF will sell the product at an optimal price or be solely profit-driven. Most likely, this will not be an issue since WARF will have to set the product at the market price in order to maximize their profits. Also, we are in the early stages of the patent process and may not even obtain the patent.

Another ethical issue the team faced was to operate only in areas in which they were competent. This meant that, for certain steps in the design process, the team required help from outside experts. First of all, the plastic cutting and shaping had to be completed by the mechanical engineering machine shop. Bill Hagquist, the machine shop foreman, oversaw this work. In addition, a seamstress was required to sew the fabric pieces onto the plastic pieces to finish construction of the prototype. By recruiting outside help, the design team ensured the development of the best quality product.

Throughout the design process the team remained objective and truthful in public statements. In particular, this applies to the team's design website, which provided an ongoing account of the design process. Both difficulties and successes were candidly discussed, thereby giving the public an accurate description of the state of the project at any given time. The team also avoided deception in filling out the Invention Disclosure Report (IDR) form by providing a complete and accurate description of the invention.

Future Developments

Based on client and advisor recommendations, there are possible future developments in the design of the final prototype. First of all, Dr. Tuite made a suggestion to double stitch the fabric to make the prototype more durable. Particularly, a double stitch should be used to secure the fabric that surrounds the rods because this is where the greatest force will be applied. Dr. Tuite also noticed that the thickness of the plastic piece that lies on the table could be decreased to reduce bulkiness and make more comfortable. If altered, the current thickness of about 1.2 cm would be reduced to approximately 0.75 cm. This decrease in size and thus loss of weight will only make it easier for the lab technician or radiologist to use the device. Finally, Paul Thompson, the group's advisor, made the suggestion of possibly having detachable fabric. If the fabric could be removed from the device, it could easily be washed or even replaced. The customers would only have to buy one set of the arm supports. After that, any worn out or broken parts could simply be ordered and replaced. This is beneficial because of the high cost of some parts, particularly the plastic ones. Two potential methods of making the fabric detachable are snap buttons or Velcro©.

As the process of refining this device continues, the above suggestions will be incorporated. This will ensure that the continued modification of the design will result in the highest quality product.

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Appendix A

Product Design Specifications (PDS)

May 5th, 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 the 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 and above their heads to allow access of the x-rays. In older individuals, 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. The design must also be small because a pair of platforms must be able to rest on the narrow radiologic table.

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. The devices should be able to hold the arms of a 600 pound patient (twice the weight the table can hold). As a result, it can be predicted that one arm support should be able to hold a maximum of about 33.5 pounds.

c. *Accuracy and Reliability:* The devices must be sturdy and be able to hold at least 16.7 pounds - the predicted weight of an arm of a 300 pound patient (the radiologic table is limited to patients of 300 lbs or less).

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
- Ability to support a maximum arm weight of 30 pounds

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 7.5 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. Prototype Weight = Find this!

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 to build one prototype of a platform was $307.08. Since most of this cost includes labor, this product could probably be mass-produced at $50 per platform.

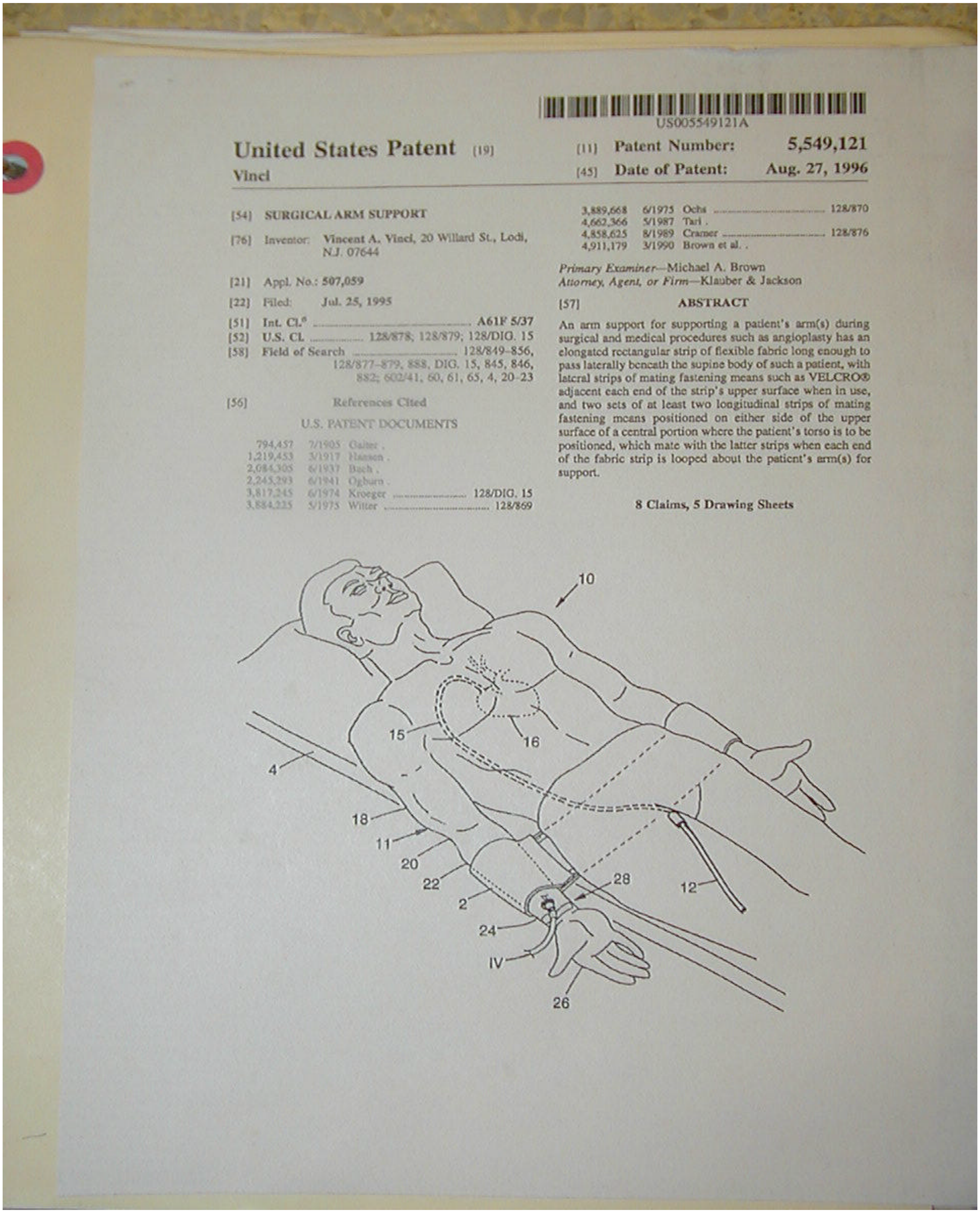
3. Miscellaneous:

a. *Standards and Specifications*: No special regulations have to be met.

b. *Customer*: Intended use is for people over 55. Must be comfortable (e.g. no sharp edges, padding, and angle/length fitting), adjustable, removable, and capable of withstanding pressure from the arm.

c. P*atient-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."



US005549121A

United States Patent [19]

Vinci

[11] **Patent Number:** **5,549,121**

[45] **Date of Patent:** **Aug. 27, 1996**

[54] **SURGICAL ARM SUPPORT**

[76] Inventor: **Vincent A. Vinci**, 20 Willard St., Lodi, N.J. 07644

[21] Appl. No.: **507,059**

[22] Filed: **Jul. 25, 1995**

[51] **Int. Cl.**^{6} **A61F 5/37**

[52] **U.S. Cl.** 128/878; 128/879; 128/DIG. 15

[58] **Field of Search** .... 128/849–856, 128/877–879, 888, DIG. 15, 845, 846, 882; 602/41, 60, 61, 65, 4, 20–23

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[57] **ABSTRACT**

An arm support for supporting a patient's arm(s) during surgical and medical procedures such as angioplasty has an elongated rectangular strip of flexible fabric long enough to pass laterally beneath the supine body of such a patient, with lateral strips of mating fastening means such as VELCRO® adjacent each end of the strip's upper surface when in use, and two sets of at least two longitudinal strips of mating fastening means positioned on either side of the upper surface of a central portion where the patient's torso is to be positioned, which mate with the latter strips when each end of the fabric strip is looped about the patient's arm(s) for support.

8 Claims, 5 Drawing Sheets

United States Patent [19]

Doughty

[11] 4,223,862

[45] Sep. 23, 1980

[54] PATIENT SUPPORT APPARATUS

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[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, 187

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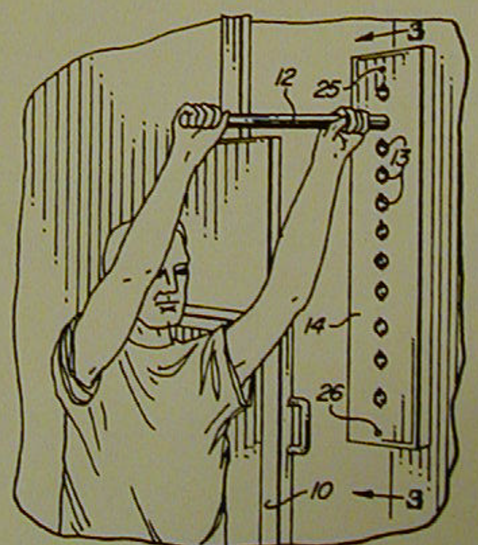
Attorney, Agent, or Firm—LaValle D. Ptak

[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**

Arm Length Data:

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

Arm Length Analysis:

Male (M) or Female (F)	Armpit to Elbow	Elbow to wrist	Forearm Circumference - widest part
	(cm)	(cm)	(cm)
Students and Advisors Standard deviation	3.826	1.297	2.250
Elderly standard dev	1.383	2.095	3.877
Overall standard dev	**4.412**	**1.604**	**2.956**
Overall Maximum	**32.80**	**27.90**	**36.80**
Overall Minimum	**19.10**	**21.60**	**22.50**

AVERAGE	27.60	25.90	26.40
Elderly AVERAGE	21.30	25.10	28.30
Overall AVERAGE	**25.50**	**25.60**	**27.10**
Range for 68% of this population (within 1 deviation of mean)	**21.09 – 29.91**	**24.00 - 27.20**	**24.14 - 30.06**
Range for 95% of this population (within 2 deviations of mean)	**16.68 – 34.32**	**22.39 - 28.81**	**21.19 - 33.01**
Range for 99% of this population (within 3 deviations or mean)	**12.26 – 38.74**	**20.79 - 30.41**	**18.23 - 35.97**

*** 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. Using a 500 mL beaker, measure the volume of the water 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 9.8 = 4.5 N

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 be close to 5.58 %, the approximate maximum weight that an arm support device must hold is: 5.58% x 300 lb = 16.74 pounds

Appendix E

Qualitative Testing Results: Comfort and Ease of Use Rating for Radiologic Arm Support

Table : Test #1 - Comfort and Ease of Use for Platform

Trial Number	Comfort Level (Recorded from patient-student)	Ease of Use (Recorded from doctor-student)
1	10	7
2	10	6
3	8.5	8
4	8	9
5	9	9
6	10	8
7	8	9
8	9	6
9	7	8
10	10	8
11	10	9
12	8.5	8.5
13	10	9
14	8	7
15	8.5	7.5
16	9	8
17	8	8
18	10	9
19	7.5	7.5
20	10	9.5
	Average Value = 8.95	Average Value = 7.90