ADJUSTABLE ARM FOR HOLDING AN ULTRASOUND PROBE DURING PERIPHERAL NERVE BLOCK PROCEDURES

Biomedical Engineering Design 301
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Abstract

Peripheral nerve blocks are a method currently used by anesthesiologists to prevent the sensation of pain in an entire limb during a surgical procedure. Our client performs this procedure on a regular basis with the aid of a portable ultrasound machine. He would like our team to design a device that can serve as an additional hand in the pre/post-operative room to hold the ultrasound probe. We have divided the proposed device into three components including the cart clamp, extendable arm, and probe holder, brainstormed possible prototype solutions, and evaluated these design alternatives based on the essential characteristics of each. By the end of the semester, we plan to construct a working prototype combining the best choice for each component; testing and further prototype development will follow in future semesters.

Problem Statement

Ultrasound imaging is used by many physicians and technicians in the medical field to place nerve blocks. Unfortunately, to simply place the block requires both of the hands of the physician. If any other job needs to be done at this time, such as to thread a catheter, the physician is unable to do so without putting something else down. This device should act as an additional hand in that it should securely hold the ultrasound probe in one, be capable of moving to different spots on the body with the direction of the user, and be able to withstand the resistance pressure of the patient's body when placed against the body.

Background & Motivation

Anesthetics are used to eliminate the perception of pain and other sensations during surgery. The three main types of anesthesia are general, regional, and local. General anesthesia has the most widespread effects on the body because the anesthetic agent is circulated through the bloodstream. As a result, the brain, heart, and lungs are all affected, and a breathing tube is typically inserted in the patient's airway. In addition to its analgesic effects, general anesthetics also cause the patient to experience amnesia so there is no conscious recollection of the surgery. While general anesthesia is practical for more extensive surgical procedures, it is relatively more dangerous than other anesthetic methods due to the loss of protective reflexes such as coughing and breathing (Mayo Clinic 2006).

Local anesthesia and regional anesthesia are both used to block pain in a specific part of the body while allowing the patient to remain alert. In contrast to general anesthesia, the patient's protective reflexes remain intact. A smaller dose of anesthetic is required in local anesthesia, and it is typically injected into the site of the procedure. For example, anesthetic can be injected in the direct vicinity of a cut which needs to be stitched up (Mayo Clinic 2006).

Regional anesthesia involves the injection of a larger amount of anesthetic to eliminate pain in a selected region of the body, such as an arm or a leg. This procedure is also known as a nerve block, because the anesthetic is injected through a large bored needle around a nerve or series of nerves that serve the appropriate region of the body. For example, an injection may be administered in the brachial plexus to eliminate pain in the arm (Figure 1). The anesthetic agent works by interfering with sodium and potassium currents into cells, thereby preventing nerves from reaching threshold and firing action potentials (eMedicine 2007).

Using nerve blocks to anesthetize a region of a patient's body can be favored over general and local anesthetic for a variety of reasons. First, it is considerably safer than general anesthesia because the patient's protective reflexes are not altered. Also, a smaller amount of anesthetic can be used in the procedure. In contrast with local anesthetic, there is minimal distortion of the surgical site because the anesthetic is not injected directly into the site. However, performing a nerve block requires a large amount of anatomical knowledge to reduce the risk of accidental nerve laceration or intravascular injection (Toronto Western Hospital 2006).

Figure 1. Placement of an ultrasound probe in the brachial plexus region of the upper arm for a peripheral nerve block procedure.

Beginning in the 1990's, it became increasingly common for anesthesiologists to use ultrasound imaging to guide needle placement during the performance of nerve blocks in the periphery. Without the use of ultrasound, the success rate of the procedure is around 80 percent, because accurate delivery of the anesthetic is dependent on surface landmarks on the body. Ultrasound allows the anesthesiologist to visualize the nerve as well as the surrounding vascular, bony, and muscular structures. In addition, the real-time movements of the needle can be visualized for accurate placement and complete delivery of the anesthetic about the nerve (Toronto Western Hospital 2006).

During performance of peripheral nerve blocks, an anesthesiologist is commonly required to perform various tasks simultaneously. For example, one hand is required to hold the ultrasound probe and another hand is required to insert and manipulate the needle. Ejection of the anesthetic from a syringe requires the hands of another individual. In addition, it is sometimes necessary to thread a catheter through the needle for delivery of the anesthetic in the appropriate tissue. An arm to hold the ultrasound probe would simplify theses tasks considerably for anesthesiologists performing peripheral nerve blocks.

DESIGN CONSTRAINTS

In order to fulfill the requirements requested by the client, the device must satisfy the following basic set of constraints (Appendix A):

- ➢ Attachment to the ultrasound machines used at UW Hospitals (manufactured by SonoSite and GE) must be possible (Figure 2)
- ➢ Probes of varying shapes and sizes must be held at the free end
- ➢ The arm must extend up and over the body of the patient to work on the side of the body opposite the machine itself
- ➢ Fine motion and positioning must be easily performed with the force of one hand
- ➢ Stability of the arm must ensure that it does not move a substantial distance (± 0.5”) from the target location while withstanding the opposing pressure created by the patient’s body

Furthermore, the device will experience heavy daily use once in place at the hospital, so its moving parts must be durable and easily replaceable in the event of damage. All parts must have a surface that is able to withstand chemicals in the environment such as common cleaning solutions and the ultrasound gel used during each procedure.

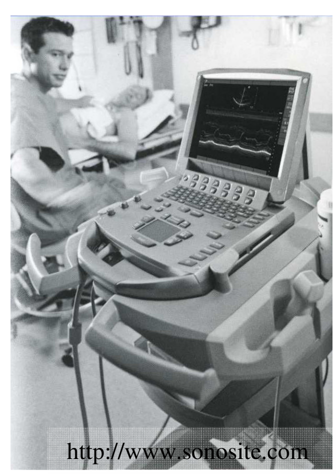

Figure 2. Sonosite ultrasound cart

Without being excessively bulky and thus obtrusive, the probe holder must be able to grasp at least three uniquely shaped objects with enough force to maintain control without damaging the probe. The ergonomic nature of the probe holder is especially important due to the physician’s close contact with this component of the device during positioning and manipulation of the probe. While the holder must satisfactorily perform its duties, it should not prevent the physician from using familiar motions during the nerve block procedure.

In order to ensure that the comfort of the patient is not diminished with the use of this device, it must be designed so as not to exert excessive pressure on the patient's body during both relaxed and contracted muscle states. Specific pressure-pain thresholds (PPTs) differ significantly between regions on the human body as well as between patients of different genders; based on a review of primary literature, the lowest level of pressure that may cause a pain response was approximately 25 psi, which occurred in the biceps brachia of female study participants (Nussbaum et al. 1998). Additional sources evaluated pressure thresholds in other regions; in the upper thigh, the maximum pressure used in a 1995 study by Liu *et al.* was also approximately 25 psi, while in more distal muscles, a PPT range of 36-160 psi was recorded (Rolke *et al*. 2005).

The entire device must be attached to the ultrasound cart, which was several feet from the patient and gurney during a procedure observed by the team. To avoid compromising the stability of the cart, the arm and probe holder [especially at the free end] must be as light as possible. To further minimize the spatial impact of the device, its components should have the ability to change position (e.g. retract or fold) in order to store the device in a reasonably small space while not in use.

Some of the characteristics of the device may fall under control by hospital and/or FDA regulations, which are currently unknown. Finally, the introduction of new ultrasound or gurney equipment in the future may necessitate redesign of device components in order to maintain its universal capabilities.

ALTERNATIVE DESIGNS

For this particular project, we have decided to split the design into three different components:

1) Cart clamp: Connects the whole device to the handle of the ultrasound cart
2) Arm: Extends up and over the patient, allowing for placement of the probe on the patient's body
3) Probe clamp: Securely holds the probe and is finely adjustable for viewing of nerves from varying angles.

We have come up with three different designs for both the cart clamp and arm and two designs for the probe clamp. All of our designs allow for some variation (e.g. joint type, component size/shape) that we expect to narrow down during future testing phases.

Proposed Cart Clamp Designs

1: The Buckle Clamp

The first proposed design was inspired by the buckles on ski boots. There would be a 270º cuff that could be placed around the handle of the ultrasound cart. To complete the full circumference of the cart handle, there would be a buckle that could be adjusted to varying degrees of tightness. One mode of operation could include a strap with teeth fed into a one-way spring loaded stopper until the strap was mostly tight; a lever on the end of the strap connected to the cuff would be snapped shut to fully secure the clamp in a tight, closed position. Figure 3 displays the type of buckle under discussion, a product that is easy to find and can be purchased for as low as $10.00. This type of one-way strap would also allow for a ratchet-type tightening system if desired by the physician for more rapid adjustment. In such a system, the ratchet could be "cranked," each time feeding more of the strap through the stopper until the desired level of rigidity was reached. This would also replace the need for a large buckle that may require a lot of force to close.

Figure 3. Ratchet-style toothed buckle.

Another option with this buckle type of device would be to use a loop that was attached to a lever on one side of the cuff that could be placed in a series of preset teeth that were on the opposite side of the cuff. The loop could engage a different setting of teeth depending on the diameter of the cart handle and the necessary level of tightness, and then the lever would be snapped into place (Figure 4).

Figure 4. Lever-style toothed buckle.

In either case, the inside of the cuff would be lined with dense foam. This foam would be thick and pliable enough to mold to any size of handle that it was wrapped around and would therefore allow this type of clamp to be used with both the GE and Sonosite ultrasound carts.

This design has a few potential issues that need to be considered. First of all, the type of foam that we would be using has not been fully researched; we cannot judge, therefore, that it would have a high enough coefficient of friction to prevent a heavy arm from slipping and rotating downwards. This effect could be amplified in the case of the Sonosite arm because it's triangular, and would have 3 points of intense pressure with limited pressure between those points, as opposed to a circular handle which would have a constant pressure all along the circumference. Another question that we must address is how large the buckle will have to be to allow the physician to operate it easily while still not being so bulky as to be obtrusive.

2: The Strap Clamp

The second design that we have chosen is effectively a strap of nylon (or other flexible material) that is wound around the cart handle. A feeding/stopping mechanism would be used once again to allow the strap to move easily in one direction without allowing backward slippage (Figure 5). The strap would be placed around the cart handle, fed through the tightening mechanism, and pulled to its necessary level of tightness. Corner "brackets" could be fed onto the nylon cord that could be placed around the corners of the handle (on the triangular Sonosite cart) drastically reducing the chances of the clamp rotating downwards under the weight of the arm.

http://www.grizzly.com

Figure 5. Nylon strap set-up including corner brackets and a stopping mechanism.

The advantages of this design are very clear; the nylon cord is easily adjusted and the addition of brackets would make this design extremely well-suited for the Sonosite handle. However, the GE handle is circular and the brackets could not be effectively used on it; using nylon alone would cause the clamp to have a much greater chance of slipping when the weight of the arm is applied.

3: The Screw Clamp

This design based on a nut-and-bolt tightening system (Figure 6). A cuff would be constructed that fits around the handle of the cart, and the inside of the cuff would be lined with dense foam. This design varies from the buckle design however, in the fact that this cuff would have two flanges that would

Figure 6. Clamps tightened by a nut and bolt.

extend parallel to one another in the horizontal plane. Each flange would have a hole through which a bolt could be fed. The bolt would pass through the holes and protrude out on the underside of the bottom flange. A wing nut would be fed onto the bolt and spun, forcing the lower flange closer to the upper flange and thus tightening the cuff.

The problems with this device are much like those of the buckle clamp. The question of slipping is still an issue as well as that of ease of operation. If too small of a nut is used, the glove-wearing physician may have difficulty tightening the nut. However, too large of a nut and it may start to protrude from the cart and become obtrusive.

Proposed Arm Designs

For the arm to function properly, it would need to be able to exercise two main functions: long range motions and fine adjustments. Gross adjustments would involve extending the arm from the ultrasound cart across the body of the patient and moving it up and down along the patient's body, depending on the placement of the nerve block. Fine adjustments would include searching for the actual nerve with the ultrasound probe and maintaining the probe's position over that nerve. Our group has come to the conclusion that the fine adjustments could be most effectively accomplished with a gooseneck, a part that is commonly used as microphone extensions on podiums. The gooseneck would provide the physician with a large range of motion in any direction and depending on its diameter may offer varying levels of resistance. By finding a balance between resistance and motion, we should be able to choose a gooseneck that the physician can use to place the probe in its target position and then have it stay in place.

One issue to consider with a gooseneck, however, is that they are usually made of metal and therefore can be very heavy. Excess weight could cause strain and torque on the cart handle, causing it to slip down. To avoid adding unnecessary weight to the device, we plan to minimize the length of the gooseneck (if possible) while maintaining a maximal range of motion.

1: One Member + Long Gooseneck

This design would have only one member that would be connected directly to the cart clamp on one end and the gooseneck on the other. It would be connected to the cart via a ball and socket joint to allow a range of motion both side-to-side (different areas of the patient's body) as well as up and down (closer to or further from the body). The bar could be made of any type of rigid material. The advantage to this design is that it would be extremely easy to operate; the physician would only have to pull the bar down over the body and then use the gooseneck to make the finer adjustments. When finished, it could be pushed back into place. The ball and socket joint could also be made according to our specifications in which it would be tight enough to withstand the force from the patient's body while still allowing motion when directed by the physician. The disadvantages with this design are that the gooseneck would need to cover a wider range of the patient's body, making it longer and adding weight to the arm. Also, depending on the size of a patient, the one member may not be able to cover the range of distance that is necessary.

2: Two Members + Medium Gooseneck

The second design would consist of two members with a gooseneck at the end. These two members could be connected to each other in a number a different ways, including but not limited to a ball and socket joint, a locking mechanism, or simply a hinge. This would enable the long range motion of the arm to extend further in two different directions. Telescoping, or some other type of lengthening mechanism, would also allow the distance that the arm is able to travel in those directions to be greater. Allowing one of the members to rotate would also greatly increase the variability of the motion.

The justification for adding a second beam is to allow the arm to extend further over the body of the patient, allowing for a shorter gooseneck and decreasing the expected weight of the arm. Problems may arise if we are not able to find a way to easily make the arms collapsible on each other or rotated away for storage as they would be much more obtrusive than a single beam. Another question arises when discussing rotation due to the fact that using a shorter gooseneck could transfer more force to the beam; if rotation occurs too easily in any joint, the member could rotate out of place. However, this is something that could be solved with proper restrictions on the freedom of rotation for each joint.

3: Multiple Members/Joints + Short Gooseneck

The final design that we have decided upon would consist of multiple (2+) members and a short gooseneck. The shape of the members as well as the type of joints have yet to be determined, however, the increase in number of joints gives more freedom to the range that our device could have. For example, curved members would form an arch that could extend more gracefully over the body of the patient. In addition, having a greater range of extension would allow for a much shorter gooseneck, resulting in the lightest design thus far. If possible, the joints could be arranged in such a way that, depending on the size of the patient, they could be extended or remain collapsed together according to the desires of the physician. Choosing joints capable of being locked into set positions would prevent the unwanted retraction of arm members if any force is applied. In addition, if all of the members are able to retract onto each other, the storage area of this device would be minimal.

Determining the details of this design becomes difficult when discussing its retraction. If all of the separate joints lock into place, we would either need to find a mechanism able to release them all in one motion or the physician would be required to unlock them individually which would be inconvenient. Furthermore, depending on the material and thickness of the joints, they could be bulky and heavy as more were added.

Proposed Probe Designs

UW Hospital utilizes various probes manufactured both by SonoSite and GE to perform the nerve blocks. Because of this, a universal device needs to be created that connects the arm of the system to the ultrasound probe. Two clamps are proposed; one utilizes a buckle-like mechanism and encompasses most of the probe, whereas the other mimics how a hand would hold the probe and utilizes a locking rotational hinge.

1: Foam plates

The first probe consists of a Y-shaped device (Figure 7). Two pieces meet at a hinged point and are connected to the system's arm with a single rod. The hinged pieces are lined with compressible foam to avoid damaging the probe and to help increase universality by allowing the foam to conform to various shapes. Once placed around the probe, the two rigid pieces are held together with a buckle. The buckle can be closed in various positions in order to accommodate a range of ultrasound probe thicknesses. This probe would encompass the majority of the probe, and therefore would have to be ergonomically designed in order to ensure the comfort of the user. This design requires few fine adjustments, making it easily manipulated by a technician wearing gloves.

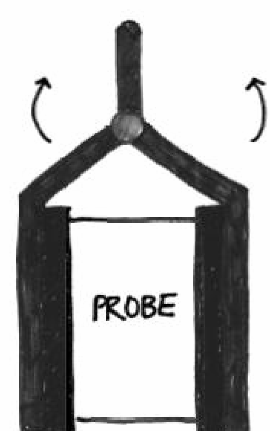

Figure 7. Proposed shape of the foam plate probe holder, with arms that swing up to release the probe.

2: Quick-release hand

The second proposed design operates on a lockable hinge in place of the buckle in the previous design (Figure 8). The area that contacts the ultrasound probe would be lined with foam as in the previous design. Two rigid pieces would form a U and meet at a point of rotation. This area would contain a gear with a detent or something that allows for rotational movement, locks in one position, and allows free rotation in the other direction as a means of release. As the user pushes the two pieces together, the tension at the point of rotation increases, therefore creating the required clamping force. In order to release the probe from the clamp, the detent would be depressed (or whatever action is required to switch the hinge to free rotation), and the clamp is easily removed. This design would ideally be small and unobtrusive, potentially allowing the technician to continue to manipulate the probe without having the clamp as an intermediate between the hand and probe.

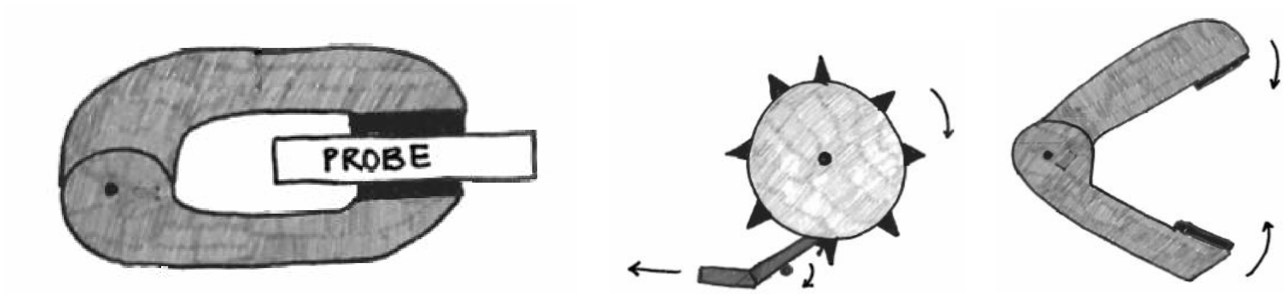

Figure 8. Proposed quick-release hand design: (left) Closed configuration, holder has minimal contact with the probe, (middle) Internal gear mechanism with stops to establish closed position with the ability to be released when the pin is disengaged, (right) Open configuration of holder demonstrating closing motion.

DESIGN MATRICES

Table 1. Evaluation of the cart clamp designs based upon essential characteristics (operation by technicians, stability due to device weight, and universality with respect to different cart handle shapes).

	Ease of operation	Stability	Universality	TOTAL
	(1-3)	(1-4)	(1-3)	(1-10)
Buckle clamp	3	3	3	9
Strap clamp	2	4	1	7
Screw clamp	1	3	3	7

Table 2. Evaluation of the arm designs based upon essential characteristics (operation by technicians, ability to store in a small space, weight, and universality with respect to different body sizes).

	Ease of operation	Storage Size	Weight	Universality	TOTAL
	(1-5)	(1-5)	(1-5)	(1-5)	(1-20)
Single member arm	5	3	3	3	14
Two member arm	4	4	4	4	16
Multi (2+) member arm	2	5	4	5	16

Table 3. Evaluation of the probe holder designs based upon essential characteristics (operation by technicians, obtrusiveness/size, and weight).

	Ease of operation	Size	Weight	TOTAL
	(1-4)	(1-3)	(1-3)	(1-10)
Quick-release hand	3	3	3	9
Foam plates	2	3	2	7

FINAL DESIGN

By evaluating our design matrices, we were able to select our best design options from each category and combine them into one final design. The buckle cart clamp was decided upon because it is easily adjustable to varying handle sizes as well as simple to operate by the physician. Also, when fully tightened, it should be able to exert enough static force as to not slip down on the handle. When evaluating the arm, we found that the two member arm received the same score as the multi-member arm. Both will provide a higher level of extension over the body than the one member arm as well as allow for a shorter gooseneck, thus permitting the arm to be significantly lighter. Our final arm design will therefore have at least two members/joints. Finally, the vise grip probe clamp was chosen because it will ideally be very easy to operate as well as smaller, making it protrude less onto the current probe and be more convenient to the physician.

By combining these options together, our final design at this point is going to be the buckle clamp attached to a 2+ member arm with a vise grip probe clamp at the end. We believe that this design will accomplish the tasks set before us by our client as well as be easy to use by the physician. However, we did meet with Dr. Kloosterboer recently and he gave us some additional information that may possibly alter our design slightly. This information included new ranges of motion that he would like our design to be able to conform to. This range may eliminate a two-member arm from our design options and also require us to use all ball-and-socket joints. We will be doing more research into this issue.

POTENTIAL PROBLEMS

One of the biggest obstacles in this project is creating components that are universal to the required situations. Because two machines manufactured by different companies are used to perform the nerve blocks, the sections of our design must account for the differences. For example, the SonoSite machine cart has a handle with a triangular cross-section, whereas the GE machine's is circular. Because we want our device to attach to these handles, we have to manufacture a part to fit both of these shapes. This may prove to be difficult because a clamp that works for the circular cross-section may not provide the required stability when used with the SonoSite machine. The same applies for the ultrasound probes: the shape of the probes is generally the same, but one is quite different. We would like to avoid having to create interchangeable parts to be used with the various machines and probes, so choosing the correct design is critical.

Other problems that may arise include providing enough resistance in the device in order for it to exert the desired force. Because the project is in the early phases of the design process, much is still unknown about what connections will be utilized, but how they should perform is known. Finding the connections that accomplish the desired tasks will most likely be a tedious task.

Because the environment for the design is a hospital, standards dictating aspects of the design may be encountered. These standards may make the project more expensive, the materials may be more difficult to obtain, and there may be an inspection to ensure our device adheres to the specified standards.

FUTURE WORK

For the current semester, we plan to work with our budget of approximately $1500 to create an inexpensive initial prototype, with the ideal prototype being constructed in future semesters. In order to accomplish this, we will first select the specific components that will comprise the two brackets (i.e. the cart clamp and probe holder) as well as those for the arm. In addition, exact measurements will be determined prior to construction. Once parts and dimensions are obtained, we will construct our prototype.

Next year, we will focus on refining our design, conforming to hospital standards, and constructing our ultimate prototype. Through testing of our prototype from the previous semester, we will have determined any changes to be made. Once constructed, additional testing will need to be completed to ensure its reliability and efficiency. We may also pursue a patent with assistance from WARF.

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APPENDIX A: **PRODUCT DESIGN SPECIFICATIONS**

Updated: March 13th, 2007

FUNCTION: Ultrasound imaging is used by many physicians and technicians in the medical field to place nerve blocks. Unfortunately, to simply place the block requires both of the hands of the physician. If any other job needs to be done at this time, such as to thread a catheter, the physician is unable to do so without putting something else down. This device should act as an additional hand in that it should securely hold the ultrasound probe in one, be capable of moving to different spots on the body with the direction of the user, and be able to withstand the resistance pressure of the patient's body when placed against the body.

CLIENT REQUIREMENTS:

- The device needs to be attached to the ultrasound machines used at UW Hospitals (manufactured by SonoSite and GE)
- It needs to be able to hold probes of varying shapes and sizes at the free end
- It needs to extend up and over the body of the patient to work on the side of the body opposite the machine itself
- It needs to be able to be moved and positioned with the force of one hand
- When put into place on the body, it needs to be stable enough to remain at a target location, withstanding the opposing pressure created by the patient's body

DESIGN REQUIREMENTS:

1. Physical and Operational Characteristics

a. *Performance requirements*: The device will be used several (10+) times every day. It will be operated in a sterile environment. It should be portable and easily removable from the docking position.

b. *Safety*: Due to the fact that this device may have direct contact with patients, there may be several FDA or hospital rules that we need to follow. Also, the device needs to be compact enough so visibility or other abilities of the physician are not hindered.

While the device must exert enough pressure to overcome the tissue resistance of the body, it should also be able to be displaced by any extraneous movement of the patient's limb. This would avoid unnecessary pain being inflicted on the patient by excess pressure.

> Pressure exerted on the patient by the device should not exceed 24 psi (from experimental data).

c. *Accuracy and Reliability*: When placed by the physician, it is imperative that the device stays in the target location (± 0.5"), and continuously apply the desired pressure.

The physician should always have full view of the ultrasound screen while maintaining use of the arm:

> From product research, it appears that the arm must be mounted to the handles of the ultrasound cart which are located in directly in front of the screen. This will require a horizontal extension so that the arm is not blocking the view of the screen.

Accuracy is much more important than precision in this case because the locations of the nerves differ from patient to patient.

d. *Life in Service*: Provided that this arm is able to stand up to heavy everyday use (10+ times a day, 5 days a week), a big factor in its life in service will be its ability to adapt to the changing technologies. For example, the introduction of new ultrasound equipment may require the design of a different clamp for attachment to ultrasound probes.

e. *Operating Environment*: The device will be used in a hospital; therefore, it will constantly be in a sterile environment and won't be exposed to dirt or any other weather-related hazards. The biggest concern here is that it will need to be cleaned after every use so it should be made of something that does not corrode with the regular use of neutral disinfectants.

f. *Ergonomics*: The device should be able to be used comfortably by the physician, so the probe holder must not be so large around that it cannot be easily gripped. The clamp holding the ultrasound probe should be ergonomically designed if it is to be manipulated by the physician (instead of contacting the actual probe). Also, the probe should be able to be moved with only the force of one hand.

g. *Size/Weight*: The device should be small and light enough so as to not throw off the balance of the ultrasound cart that it's attached to. Also, it should be unobtrusive enough so as to not hinder the abilities of the physician while still being strong enough to maintain its position when placed. When not in use, it should be compact enough so that it can be rolled along with the ultrasound machine and not be a hazard to its surroundings.

h. *Materials*: The device needs be made of or covered with a material that can be sterilized.

i. *Aesthetics*, *Appearance, and Finish*: The finish should allow for cleaning and be visually appealing.

2. Production Characteristics

a. *Quantity*: We are going to focus on producing one prototype of the device, with the final goal of implementing at least three throughout the hospital [two Sonosite machines are in use at UW Hospital and one GE machine is used at the Madison Surgery Center].

b. *Target Product Cost*: Client has not specified at this time

3. Miscellaneous

a. *Standards and Specifications*: The design must meet any requirements imposed on devices to be used in the hospital.

b. *Patient-related concerns*: When placed across the patient's body, the arm should be at a level above the patient to maintain comfort and avoid contact with the body.

c. *Competition*: Items are available, such as articulating arms and surgical tool arms, which serve the purpose of holding instruments during medical procedures. These devices could potentially be modified for our purposes.