

# Support System for Lumbar Puncture Procedure

Mid-Semester Paper

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**Problem Statement:**

To design a specialized support system to use for lumbar puncture procedures in the sitting position. Proper positioning of the patient to open up the space between the lumbar backbones is critical for success of the procedure. Keeping the patient comfortable while maximizing the curve of the lower back to optimize the access to the lumbar interspace is important, however, it remains a difficult challenge using current positioning techniques. Currently, there is no proper seating equipment to optimize the position and comfort of the patient during the procedure. The use of the lumbar puncture technique in research is becoming increasingly significant.

**Project Motivation:**

Our client, Dr. Cynthia M. Carlsson strives to understand the effects of vascular risk factors and their treatments on the development and progression of Alzheimer's disease. She is currently conducting a clinical trial to evaluate how cholesterol-lowering medications called statins affect blood, spinal fluid, cognitive, and MRI perfusion biomarkers for Alzheimer's Disease in asymptomatic middle-aged adults at risk for the disease. To study these changes, Dr. Carlsson collects cerebral spinal fluid from patients using the lumbar puncture procedure.

**Background Information:**

The lumbar puncture procedure is performed by inserting a needle into the lower back between the lumbar backbones. Insertion is much easier when the spine is curved because it facilitates the separation of the lumbar backbones.

Currently, this procedure is done with the patient sitting on the edge of the bed, the feet propped up with a chair and the head resting on a doughnut shaped pillow on the bedside table. The patient's arms also rest on the bedside table(See Figure 1). This positioning is uncomfortable for the patient because the patient's head is approximately 3.5 inches from the table which is not permit proper air flow. Also, the patient's knees are typically in contact with the bottom of the table which adds further discomfort. The patient's arms are at the same level of the head which is also uncomfortable. Since the arms are above the heart, the patient's arms are more likely to experience a lack of blood flow. Since the patient is not supported at the sides and the bedside table is on wheels, there is the risk that the patient will fall to the side, or that the table will move away from the patient during the procedure. In this case, the spine is likely to become misaligned. In order to prevent this from happening, additional persons are required to help position and secure the patient during the procedure.

**Figure 1:** Current positioning of a patient for lumbar puncture procedure. *Left Picture:* Notice the patient's knees are in contact with the bottom of the table. Also notice that the patient's head is very close to the table, and the patient's arms are level with the head which is less comfortable than if they were lower than the head.



Currently, there is no equipment specially designed for lumbar puncture procedures; however, researchers at the Department of Neurology at Johns Hopkins Medical Institution have utilized massage chairs for spinal catheter insertion (See Figure 2) [1]. Researchers found that the massage chair provides a stable platform that allows patients to maintain proper position without effort, and without the need for additional personnel to monitor the patient. The head rest minimizes the possibility of breathing obstruction, and the seated position allows for proper spinal alignment.

One drawback to this technique is that patients who are unable to straddle their legs over the seat may be unable to sit on the chair. A second drawback that was not reported by researchers at Johns Hopkins, but that our client brought to our attention, is that this massage chair does not maximize curvature of the spinal cord possibly due to the limited range of adjustability of the chair.

**Figure 2:** The massage chair is used by researchers at Johns Hopkins for the lumbar puncture procedure. Notice that the procedure can be done without the need for additional personnel. Also, the patients breathing remains unobstructed and the arms are at approximately heart level facilitating a comfortable sitting position for the patient. *Left picture:* Notice that this seat may be difficult for geriatric patients to sit in.

<http://www.neurology.org/cgi/content/full/58/12/1859?cookietest=yes>

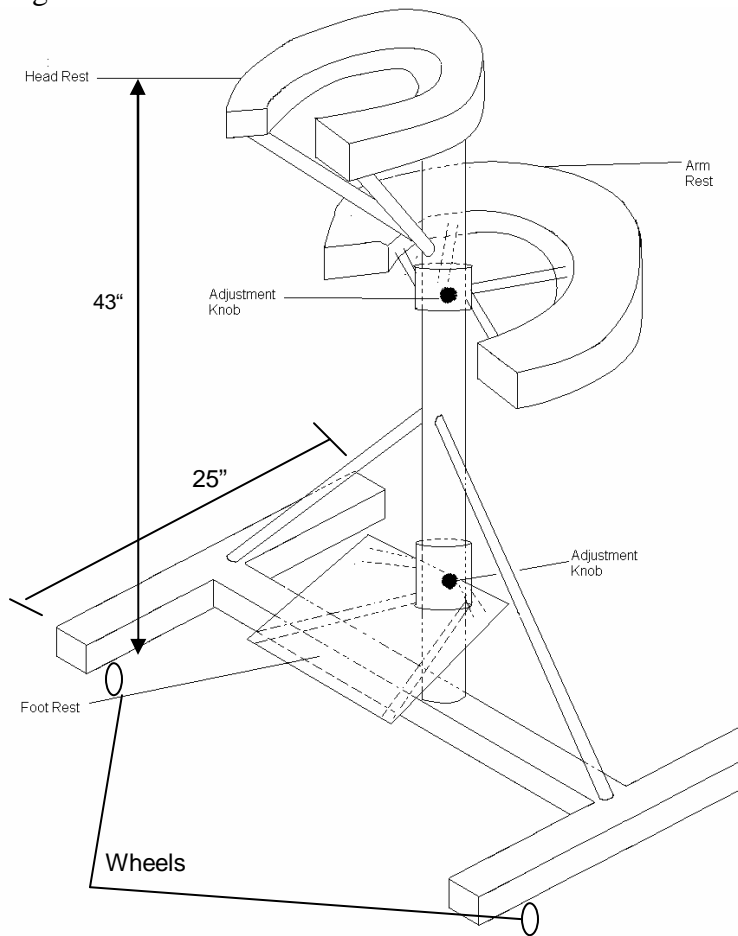


Our design must provide proper positioning of the back during lumbar puncture procedures. This means that the spinal column must be curved at a maximum point while maintaining patient comfort. The device must be used in conjunction with the bed. Therefore, the patient should sit on the edge of the bed and the device should support the head, feet and arms, in a way that is comfortable and compatible with varying patient body sizes. The device must be easily transported throughout the hospital and must be able to fit in all the hospital rooms. The device must cost less than \$500. Refer to PDS in Appendix 1.

### **Design #1- One-Piece Unit**

Our first proposed design is a one-piece unit, where the head, arm and foot rests are attached to a central column. The central column is adjustable and can vary in length using a system of push button tabs similar to those used on standard crutches. The head rest is directly attached to this central rod and can be adjusted vertically by raising and lowering the central column. Two cuffs, one attached to the foot rest, and one attached to the arm rest, are placed over the central rod and can slide vertically and are held in place with a screw that can be tightened and loosened by hand with an adjustment knob.

**Figure 3:** Diagram of proposed one piece unit. Central column, arm rest, and foot rest are independently adjustable. The headrest raises and lowers vertically with the central column. For simplicity, the central column push button tabs are not shown in this diagram.



The entire one-piece unit is supported by a base, which has two supporting rods connecting to the central rod. For transportation, the base of the unit has wheels that can be locked in place with brakes when being used by the patient.

Some advantages of the design include ease of transportation and proper weight distribution throughout the unit. Since the device does not have any removable parts and has lockable wheels, it can be easily transported from room to room. Also, since there is

only one central column, patients with long legs should find it easy to avoid contact with the column. This is a significant difference from the current positioning technique where tall patient's legs are frequently in contact with the bottom of the bedside table.

Furthermore, the broad base and the support columns help stabilize the device and prevent it from leaning from side to side when in use. Since the device can be rolled towards the bed, it avoids issues that obese or arthritic patients may experience if they had to sit in a chair.

Although all three of the rests can be adjusted, there are several disadvantages to this design. First, this device may not give the maximum curvature since the foot rest cannot slide towards or away from the user. Although adjusting the feet vertically is important in patient comfort and in providing spinal curvature, positioning the feet properly in relation to the arms and head is also important in curving the spine especially with tall patients. Next, the design consists of several adjustment knobs on the central rod. This device may be difficult to fabricate because of the many moving parts. In addition, the cuffs need to fit vertically along the central rod and they would also need to adjust in diameter to account for the varying diameter of the central rod when it extends.

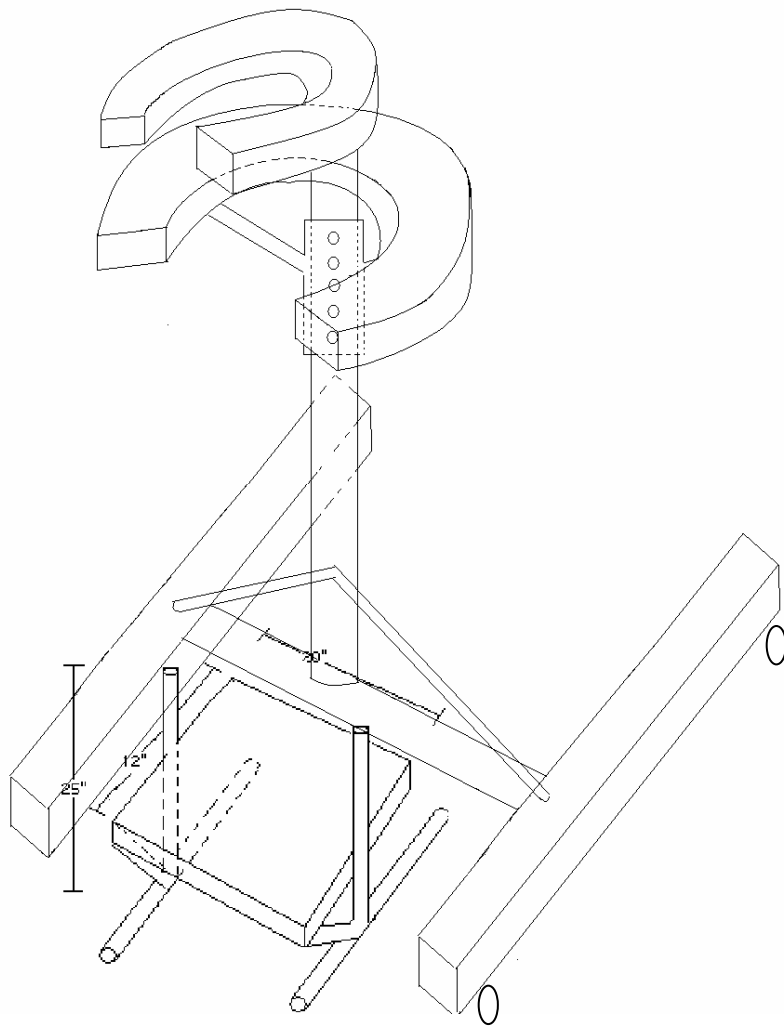
### **Design # 2 – Two Piece Unit**

The second design option is a two piece stand-alone unit. The base has a central column with an attached head rest and arm rest. The column will move up and down at approximately half of the unit's height, raising and lowering the headrest. The head rest will be similar to those on massage chairs, with a hole in the middle (See Figure 2). The arm rest will be attached to the central column by a cuff so that it can slide vertically along the column to adjust the height. The arm rest will be large and curved in shape.

Both the head rest and arm rest will have adequate padding. The base will have locking wheels to facilitate transportation.

The foot rest is a separate unit that is fully adjustable. It will have a platform attached to two posts on the base of the footrest, one at either side. It can be moved closer or farther from the bed, raised or lowered, and the angle of the foot rest can be adjusted to fit the patient's needs. The footrest will be able to lock onto the base during transportation.

**Figure 4:** Two piece unit diagram. Locking wheels for transportation, adjustable arm rest and head rest. Separate foot rest that has adjustable angle and height. For dimensions see Figure 3.





The greatest advantage to this design is the improved adjustability, which translates to better curvature of the spine. Since the foot rest is not attached to the base, it can be moved horizontally with respect to the bed, head, and arms to accommodate patients with varying leg lengths. Furthermore, having the foot rest as a separate unit makes adjustment of the angle of the platform easier.

Patient comfort was taken into account for all of these proposed designs. The padding on the arm rest will help prevent neuropathy, since the patient must remain in the same position for an extended period of time during the procedure. Also, the hole in the middle of the head rest and the open area below promote better air flow for breathing. By having an adjustable foot angle, the patient can rest his or her feet in the most comfortable position. Also, the legs can be positioned so they do not come in contact with any other parts of the device.

Stability is another important factor in the design since patients must remain still during the procedure. This unit will have a wide base with sturdy supports to prevent it from tipping from side to side. Furthermore, the wheels used during transportation will lock when the unit is in use to prevent it from rolling.

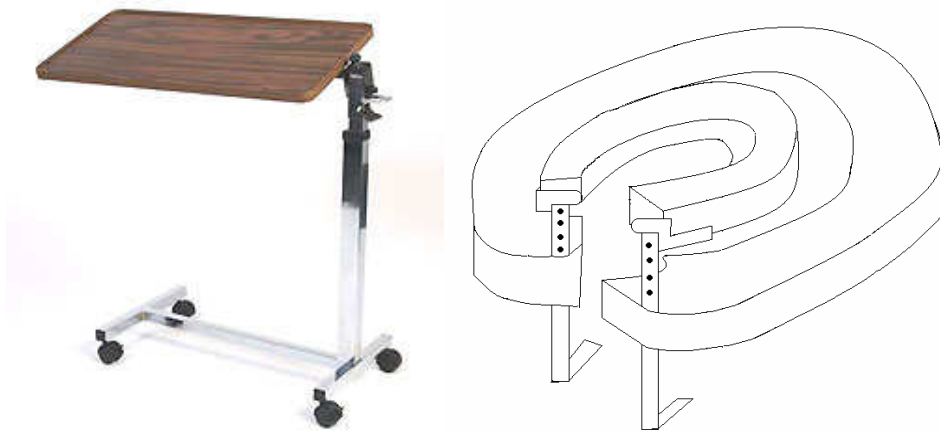
The biggest problem with this set-up is the difficulty transporting both pieces. To aid in transportation, the foot rest will attach to the base unit so it can be rolled as a single unit. This feature will also help ensure that the pieces do not get separated during transportation or storage.

### **Design # 3 Table – top Unit**

The third design is a two piece table-top unit. One of its components is a separate height adjustable foot rest similar to the one used in the second proposed design. The

other component is a unit containing the arm rest and head rest. This unit will attach to the bedside table that comes standard in all hospital rooms. Clamps will hold the unit onto the table, and the arm rest will lie on the top of the table and will not be adjustable. The height of the head rest will be adjusted by putting a pin into holes at various heights. The bedside table in the hospital room is also height adjustable.

**Figure 5:** The head rest (Right) clamps onto the height adjustable bedside table(left). The arm rest is the outer ring(right) and rests on the table while the head rest (inner ring) is adjustable for height.



[www.comfortchannel.com/images/Overbed\\_table\\_h.jpg](http://www.comfortchannel.com/images/Overbed_table_h.jpg)

Most of the advantages of this design are due to its small size. Since the unit just attaches to the table, it does not utilize as much material as the other two designs and will be less expensive to construct. Due to the more compact design, it will also be easier to store, which is important because our client does not have much storage space for our product. Another advantage is that it utilizes existing equipment, the bedside table, which is already available in all of the hospital rooms in which this product will be used.

One major disadvantage to this design is that it is less adjustable than the other designs since the head rest of the table top unit is adjustable, but the arm rest is not. The limited movement of the foot rest will also affect the adjustability. Since the table is

being utilized, it will interfere with the horizontal positioning of the foot rest, thus limiting how far in and out the foot rest can be placed. This design is also less sturdy because the bedside tables do not have locking wheels, which could result in the unit slipping while the lumbar puncture procedure is being performed. Currently, a chair is propped between the table and the wall to keep the table in place. Another disadvantage of this design is that there is less air flow for the patient since the head rest of the table top unit is so close to the top of the table. The difficulty of transporting this design is another issue because the product has two pieces that will need to be carried from room to room.

### **Design Matrix**

Each of the three proposed designs were rated based on the following criteria: comfort, stability, curvature of spine, ease of manufacturing, adjustability, portability, and cost. Cost and portability were weighted less than all other criteria since the budget is nearly \$500 and since portability was not the primary issue that our client is faced with. It is much more important to provide the maximum spine curvature and comfort to the patient.

Out of possible 60 points, the two-piece unit scored highest overall with 50 points, followed by the one-piece unit and finally the two-piece table top design. The one-piece unit and two piece stand-alone unit scored equally in the comfort category while the table-top unit scored lower due to lack of sufficient air flow and since the arms will be more at the level of the head. In terms of stability, the two-piece unit and the one-piece unit were rated higher than the table top design because the latter design uses the table present at each hospital room that cannot be locked in place. Since the tables have

wheels at the base and are unstable, they do not provide proper support needed. Next, the two-piece unit was given the highest rating for spine curvature. Since the table top unit does not have an adjustable arm rest, the arms and the head will be aligned close to each other and may not allow the user to open up the spinal column as much as they could. Further, the one-piece unit received an intermediate rating since it has adjustable arm rests, but lags the two-piece unit since the foot rest cannot be adjusted horizontally. The two-piece unit also would be the easiest to manufacture since the foot rest can be ordered on-line and the components can be assembled easily. The one-piece unit would require building a central rod with adjustable lengths, and cuffs that adjust to varying diameters, which would require excessive labor. It would also require building a foot rest. Further, the two-piece unit was rated the highest for adjustability over the other two designs. Compared to the one-piece design, and the two-piece design, the two-piece table attachment allows the user control over the position of the head rest and the footrest, while the armrest is stationary and is clamped onto the table. In addition, the one-piece design is also cumbersome when adjusting the height of the head rest; since the head rest is directly attached to the length-varying central rod, every time the height of the head rest is altered, the cuffs for the arm rest and the foot rest also need to be adjusted. The one-piece design was rated highest in portability because transporting a single unit with wheels is more convenient than moving a two-piece unit. The problem with transporting the two-piece unit can be easily altered by adding a latch or a hook that enables the foot rest to attach to the main unit. Finally, the cost estimated for the two-piece table attachment is the lowest since it does not have as many supporting columns, a base unit or adjusting knobs compared to the other two designs. Refer to Appendix 2.

## Future work

Although we will be pursuing the two-piece design, some minor modifications may be necessary. As mentioned above, the addition of a latch or hook to the main unit (with the arm and headrests) to attach the footrest would help our client transport the device more easily. Next, materials needed for the design will be ordered. We are considering ordering the foot rest shown in Figure 6, from [www.office1000.com](http://www.office1000.com). Steel supporting rods, screws, hinges, cuffs and wheels need to be ordered. We are also considering purchasing a desktop massage unit from [www.massagingking.com](http://www.massagingking.com) for the head rest and arm rest components of the two-piece design (see Figure 6). Institutional Review Board approval for use on human subjects may also be obtained to test the device. Based on testing the device on teammates, adjustments to the design will be made to ensure that maximum curvature is obtained for each individual on the team while providing proper support.

**Figure 6:** Possible materials. (Left) desk top massage chair to be used for head rest and arm rest components. (Right) Possible foot rest to be used in conjunction with Two-piece stand alone unit. Specifications shown below Figures.



[www.massagingking.com](http://www.massagingking.com)

- Only the head rest and arm rest will be used
- Leather cushioning for patient comfort
- \$119



[www.office1000.com](http://www.office1000.com)

- Height range of 5-1/2" to 15" with 9 positions in 1-1/4" increments
- Textured, anti-slip platform size is 20" x 12" and mounts at an 8 degree angle
- Heavy gauge black tubular steel construction
- Locks together with button tabs
- \$91.97

## References

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## Appendix 1

### Lumbar Puncture Product Design Specification September 22, 2006

**Function:** A device should be built to properly support the head, arms and feet of patients undergoing a spinal tap procedure. Use of the device should enable patients to curl their back as much as possible to open lumbar spaces for the procedure, while providing maximum comfort. Finally, the device must be adjustable to provide support for a variety of heights and weights.

**Client requirements (itemize what you have learned from the client about his / her needs):**

- Device must fit around an adjustable height hospital bed
- Should be adjustable so the patient can be positioned properly
- The device must incorporate an adjustable foot rest, a handle, and a head rest
- Must allow for maximal curvature of the spine
- It must be sturdy and should not tip over during use or adjustment
- The device should be built within a \$500 budget

**Design requirements:**

Our goal is to design a specialized chair to use for lumbar puncture procedures in the sitting position. Proper positioning of the person to open up the space between the lumbar backbones is critical for success of the procedure. Keeping the patient comfortable while maximizing the curve of the low back to optimize the access to the lumbar interspace is important, yet remains a difficult challenge using current positioning techniques.

#### 1. Physical and Operational Characteristics

- Performance requirements:* The device will be used for thirty minutes, four to ten times a month.
- Safety:* During use, the device must provide adequate support to the patient and must be sturdy.
- Life in Service:* We would like the device to last at least five years.
- Operating Environment:* The device will be used in a hospital patient room and would not have to undergo extreme variations in temperature, pressure, and other external factors.
- Ergonomics:* The device should be able to withstand a bulk of the patient's body weight and must include cushions around the support areas to maximize comfort.

- f. *Size*: Since the device should fit within the space between the hospital bed and the wall surrounding the room, the dimensions of the device should not exceed three feet wide and three feet deep.
- g. *Weight*: The device will be transported frequently within the hospital and will need to weigh less than 50 lbs.

## **2. Production Characteristics**

- a. *Quantity*: one needed for client, however, if the product is desirable, it can later be mass produced.
- b. *Target Product Cost*: The total cost in producing the support device should not exceed our client's proposed budget, \$500. The nearest competition to the product, the massage chair, costs nearly \$200.

## **3. Miscellaneous**

- a. *Standards and Specifications*: We must obtain the Institutional Review Board (IRB) approval to test our product on humans.
- b. *Customer*: The client would prefer an adjustable angle for the footrest.
- c. *Patient-related concerns*: Since the device will be used by multiple individuals, it should be cleaned with sterilized wipes between use. The design should maximize patient comfort.
- d. *Competition*: The most popular supporting device used is a massage chair, however, our client reported that massage chairs do not provide enough curve to the spine to successfully withdraw spinal fluid. Further, there are no specialized chairs specifically designed for this procedure.



## Appendix 2

### Design Matrix

Criteria	One piece unit	Two piece stand-alone unit	Two piece table attachment
Comfort (10)	7	7	6
Stability (10)	9	9	5
Curvature of Spine (10)	7	9	6
Ease of manufacturing (10)	5	9	7
Adjustability (10)	7	9	3
Portability (5)	5	3	3
Cost (5)	4	4	5
<b>Total (60)</b>	<b>44</b>	<b>50</b>	<b>35</b>