# Neck Extender/Flexor to Facilitate Fluoroscopy Examination of an Obtunded Patient


## Team Members

Alison Boumeester
Vidhya Raju
Susan Samreth
Peter Strohm

## Advisor

Naomi Chesler, Ph.D.
Department of Biomedical Engineering

## Client

Victor Haughton, M.D.
UW Department of Radiology


May 9, 2007

**Table of Contents**

Abstract……………………………………………………………………………..………3

Problem Statement……………………………………………………………….………3

Motivation………………………………………………………………………..………3

Background Information…………………………………………………….……...4

Summary of Product Design Specifications……………………………….………..6

Alternative Solutions……………………………………………………………………..7

Preliminary Design Evaluations…………………………………………………………12

Final Design and Prototype……………………………………………………………...13

Conclusions and Ethical Considerations………………………………………………...18

Appendices

Appendix A (Product Design Specifications)……………………………………………20

Appendix B (Figures) …………………………………………………………...22

References……………………………………………………………………………….26

**Abstract**

In order to measure disk health through quantitatively reliable methods, a motorized device simulating natural neck extension and flexion during fluoroscopy examination is required. The device must not interfere with X-ray signals from the fluoroscopy imaging system and must facilitate rotation isocentric to the spine. In addition, the device must be equipped with a safety feature disabling operation for the patient's safety. A motorized system consisting of a linear actuator, a platform, a headboard, and panic button switch has been designed in order to meet the client requirements.

**Problem Statement**

Determining disk health in the cervical spine is facilitated by fluoroscopy, an imaging tool capable of capturing X-ray images of objects in motion (Schueler, 2006). Currently, in order to image the cervical spine in motion, the patient's head is moved by technicians. This process exposes hospital staff to unnecessary X-ray radiation from the fluoroscopy machine and is therefore unethical. In addition, the possibility of injury caused to the patient due to human error is also possible. Our goal is to create a device capable of simulating natural neck movement during fluoroscopy examinations in order to allow the procedure to be performed ethically and safely in an automatic way. The device will facilitate precise determination of disk health in the cervical spine of unconscious patients.

**Motivation**

Current methods of imaging the cervical spine in motion pose significant risks to both the patients and staff. Human involvement in moving a comatose patient's neck increases the possibility of injury to the patient. The patient is not able to give feedback about how comfortable he/she is during the procedure. In addition, the staff member is also exposed to high levels of radiation. Our goal is to rectify these problems by designing a device capable of simulating extension and flexion.

## Background Information

*Cervical Spine*

The region of interest during the imaging procedure is the cervical spine, a portion of the spinal cord that is comprised of seven bones. These seven bones make up the neck, which connects the skull to the thoracic spine. The cervical spine serves a variety of functions, some of which include: facilitation of diverse head movement (which includes extension and flexion) and protection of nerve bundles that link the central nervous system to the peripheral nervous system. Determining the disk health between the vertebrae in this region is integral in assessing the physiological correctness of movement of the head with respect to the rest of the body. (Saladin, 2005)

*Extension/Flexion*

Extension of the cervical spine refers to the upward movement of the jaw with respect to the neutral position. Conversely, flexion refers to the downward movement of the jaw with respect to the neutral position. Imaging the neck when it is stationary serves no purpose in determining disk health because pathophysiology in the disks is not immediately apparent. Movement forces interaction between individual vertebrae and the disks that connect them. Through analyzing these interactions during fluoroscopy, physicians are able to detect inhomogeneities caused by excess stress on certain areas of disks, and are thus able to diagnose pathophysiological conditions. X-ray images of extension and flexion can be seen in Figure 1.

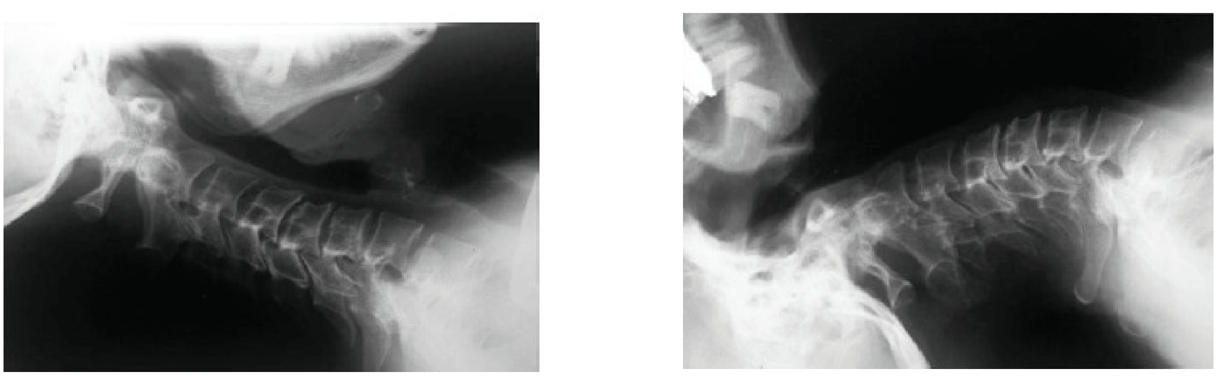


Figure 1: Extension and Flexion of the neck.

*Fluoroscopy*

Fluoroscopy (Figure 2) is a dynamic, real time, X-ray imaging tool which allows for the surveillance of an object in motion. Applied to the human body, fluoroscopy provides the ability to view an x-ray movie of the internal fluids (with contrast) and structural movements within a specific system, including the skeletal, digestive, urinary, respiratory, and reproductive systems. The mechanism for fluoroscopic imaging consists of passing a continuous x-ray beam through the body part of interest. This signal is then transmitted and translated as a live display onto a TV-like monitor. Image intensifiers are utilized to amplify and adjust image brightness (Schueler, 2000).

Figure 2: Fluoroscopic Imaging System with rotating C-arms

Fluoroscopy has many uses, but one of its primary uses is for the diagnosis of anatomical injuries. For example, this technology can be used to examine bones, muscles, joints, as well as solid organs such as the heart and lung. Furthermore, it is also a critical aid in positioning the patient during interventional procedures such as lumbar puncture, biopsies and injections of anesthetics into joints (Schueler, 2000). For our purposes, fluoroscopy will be used as a diagnostic tool for patients with spinal injuries by determining the disk health within a patient’s cervical spine via dynamic extension/flexion x-ray images. Flexion/extension x-ray studies through dynamic fluoroscopy play a crucial role in detecting instability and possible damage in the soft tissue of the cervical spine (Padayachee, 2006).

*Material Choice*

The imaging tool implemented is fluoroscopy; this limits the choice of materials that can be placed in the region of imaging. Metals, for example, are not desirable in this region because they have high levels of X-ray signal attenuation (dulling of signal intensities). More desirable materials include plastics, which do not affect the X-ray signal strength to as large of an extent. Imaging of the cervical spine will be performed laterally. Thus, we will not be constrained to not using metals directly under the fluoroscopy table, since the X-ray beam will be passing side-to-side, rather than top-bottom.

**Summary of Product Design Specifications**

Of primary concern is the safety of the patient. Many patients using this device will be obtunded and may not able to specify comfort levels. Therefore, it is imperative that the device function autonomously without human intervention, implying the need for motorization. The range of extension or flexion should span a 90 degree range, 45 degrees on both sides from the horizontally neutral position. The speed of the device should allow natural simulation of neck movement; as specified by our client, this rate is one degree per second, allotting about 1.5 minutes to traverse the whole range of motion.

The device must be universal in its ability to easily accommodate an adult’s head. It should be portable and easily assembled by one person for smooth transfer between fluoroscopy rooms. In terms of operability, one person should be able to operate the device, preferably from a remote location. This will reduce exposure to X-ray radiation. The prototype should minimize energy use and cost. The cost of constructing a single prototype should not exceed $300.00.

**Alternative Solutions**

*Gear and Motor Design*

One approach to facilitating neck extension and flexion consists of a motor driven gear which controls a headboard supported by an internal gear guide. These mechanical components will be mounted to a sturdy frame attached to the table from beneath using straps (Figure 3).

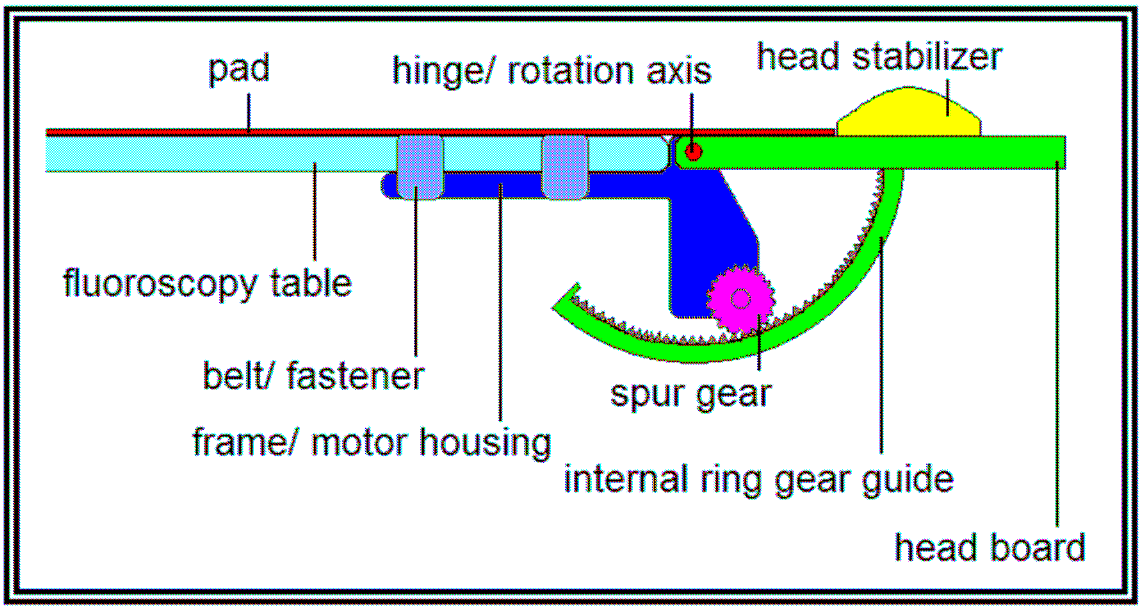



Figure 3: Gear and motor design.

The device will operate from AC converted to DC, which powers the mounted bidirectional motor (present but not labeled in Figure 3). The rotations per minute (rpm) can be adjusted by controlling the voltage. To ensure patient safety, the motor will start up smoothly so as to prevent a “kick” that could jerk the patient’s neck and cause discomfort to the patient. The torque required from this motor is enough to support the patient’s head both during the procedure and when the device is not being used.

A small spur gear will be directly attached to the motor shaft. By using a gear as an intermediate between the motor and internal gear guide, a higher rpm motor can be used to achieve slower headboard rotation. This spur gear will completely mesh with the teeth of the internal gear to ensure there is no slipping or other mechanical failure.

The headboard and internal gear guide will be conjoined such that as the guide is driven, the headboard will rotate with it. This guide can be cut from an intact internal ring gear, such that when attached to the head board, the center of rotation is about the hinge. The arc cut for the guide will be at least ninety degrees to give a full range of motion, but it must also be small enough to achieve negative 45˚ without retracting into the underside of the table. An appropriate and reasonable range for this arc is between 110˚ and 130˚. On the free end of the guide, a stopper or block will prevent the spur gear from driving beyond the end.

<u>Advantages</u>

- Portability: relatively small size allows for easy attachment and storage
- Rate of rotation: design elicits a constant, steady rate of rotation throughout range of motion

<u>Disadvantages</u>

- Cost: highly specified motor may need to be custom built, which can be expensive
- Safety: in case the specified motor is not obtained, compromising the design may reduce patient safety and prevent other specifications from being met, such as headboard rotation speed
- Applicability: may not attach to all fluoroscopy tables

*Worm Gear Design*

Another approach involves a fusion between a motorized worm gear and rack and pinion to rotate the headboard (Figure 4). The top of the rack will be a smooth roller guide, so it is not fixed to the headboard during operation. Again, the headboard will rotate about a hinge level with the table surface, and the mechanical components mount to a frame strapped to the fluoroscopy table from beneath.

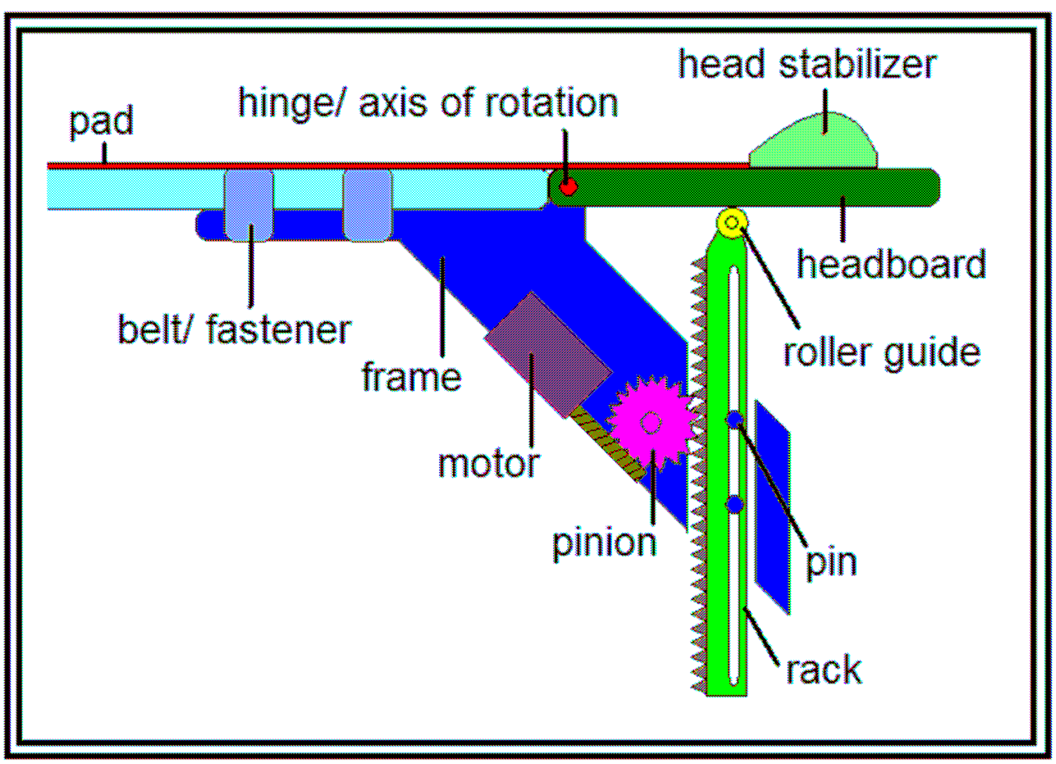


Figure 4: Worm gear design.

The torque and voltage specifications for this bidirectional motor are the same as for the first design. The same safety considerations also apply. This motor's shaft must be grooved, just as a screw is. This way, when meshed with the pinion, the spinning shaft rotates the gear. The difference in size between the shaft and gear means that the pinion rpm is lower than the motor. This configuration between the motor and gear is also known as a worm gear, but since the gear is also part of a rack and pinion, the components are referred to separately.

The motor driven pinion gear controls the vertical position of the rack, also referred to as a shaft. The rack is a toothed shaft driven by a partnered pinion gear. To hold this rack in a vertical position, a groove or track runs the length of it, and two pins are fitted. These pins ensure that only translation, not rotation, of the rack will occur. As this shaft is raised and lowered, the headboard does the same. The position of the shaft head beneath the headboard is not constant during operation, thus a roller guide will allow free movement while providing the same support. The headboard will attach and rotate about the same axis as in the previous design. These two designs differ in the direction and manner in which the force is applied. A sturdier material will be needed in the worm gear design to account for the more direct and changing forces.

Advantages

- Portability: easy installation and removal
- Rate of rotation: design provides a constant, steady rate of rotation throughout range of motion; upper range of motion can go beyond 45 degrees

Disadvantages

- Cost: custom parts will increase expenses
- Complexity: many moving parts may increase chances of mechanical, electrical or structural failure
- Size: design is bulky and has potential of hitting floor or expensive medical equipment
- Safety: large size may increase stress on belt attachment system and compromise patient's safety
- Applicability: may not attach to all fluoroscopy tables

*Linear Actuator Design*

The third design (Figure 5) is similar to the previous two in that the headboard will rotate about a hinge. The hinge will be made of a low mass attenuation material, so as to minimize the amount of interference with X-ray imaging. The rotation will be controlled by a linear actuator that drives a shaft upward and downward at a constant rate. This actuator will attach to a Z-shaped board, and adjustable straps will be attached to secure the device to the fluoroscopy table. The vertical component of the Z-shaped frame will need to extend as much as three feet below the table. The design requires the materials to be sufficiently strong in order to resist any deformation.

As mentioned before, the vertical movement of the actuator will be driven by an internal electric motor. This motor will be powered by an external power supply, which can be plugged into an electrical outlet. In order to adjust the speed of the actuator, the power supply must convert AC signal to DC signal and allow for adjusting the voltage to a specific amount. Varying and setting this voltage will allow fine adjustment of the actuator speed in order to provide the appropriate rotational rate. Additionally, one can also purchase an actuator with the desired speed and length. Calculations of the final dimensions will determine which linear actuator to purchase.

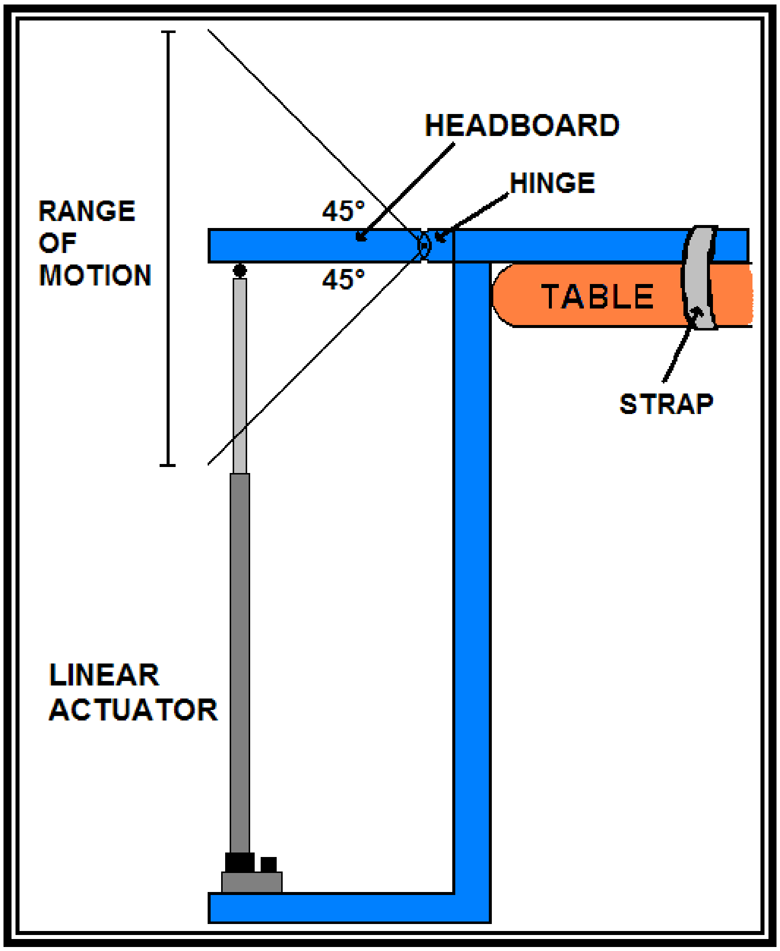



Figure 5: Linear actuator design.

Advantages

- Simplicity: design can be constructed from three main pieces, actuator, headboard and Z-shaped frame
- Portability: easy installation and removal
- Power: AC power source which is readily found in hospital setting
- Cost: most materials are inexpensive and readily available

Disadvantages

- Size: length of device may interfere with medical equipment below table
- Safety: patient safety may be compromised if material is not strong enough
- Rate of rotation: rotation speed slows as the device reaches its limits of rotation

**Preliminary Design Evaluations**

The three designs were compared in early stages of the project in the form of a design matrix. The team members evaluated and discussed the designs by certain criteria, as seen in the design matrix (Table 1).

| Criteria | Weights | Linear Actuator | Worm Gear | Gear and Motor |
|---|---|---|---|---|
| Feasibility | 40 | 39 | 20 | 25 |
| Safety | 30 | 25 | 27 | 22 |
| Mechanics | 20 | 16 | 15 | 15 |
| Aesthetics | 10 | 6 | 6 | 9 |
| Totals | **100** | **86** | **68** | **71** |

Table 1: Design Matrix and Design Alternatives

The criteria evaluated in this matrix are safety, feasibility, mechanics and aesthetics. After individual evaluation of the designs, the team came together to discuss ideas and assign weights to each criterion. The highest weights were given to the most crucial specifications that needed to be met. Feasibility in one semester was of the utmost concern, followed by safety, mechanics and aesthetics. The team then evaluated each of the designs and designated a point value out of the total weight for each category.

As seen in the matrix, the linear actuator design received the highest score and thus was chosen as the final design. Due to the simplicity in its design, it received the highest score for both mechanics and feasibility. This design was considerably less complex than the other two, and a prototype could be completed within one semester. The full rotation could be easily met by this design, and a relatively steady rate of rotation could be implemented either by converting the power supply or purchasing an actuator with the desired actuator speed. Safety also scored relatively high, although not the highest due to the possibility for material failure. This can be easily resolved by choosing sturdy, low mass attenuation material that does not interfere with the imaging.

The gear and motor and worm gear designs received similar overall scores. They were similar in design, and the lower scores are mainly attributed to the feasibility factor. Both required parts that had to be custom built, thus increasing the expense and making it rather difficult to stay within the $200-250 budget. Safety was also an issue in that the high number of complex parts could potentially lead to a lot of problems.

**Final Design and Prototype**

The completed prototype integrates simple circuitry that allows the patient as well as the staff to control the device in order to ensure safe operation. The motion is facilitated by a linear actuator. The details of the framework of the design are described below.

*Mechanics*

*Wood Frame* - This aspect of the design consists of four main components: a wood frame, a headboard, a linear actuator, and a roller guide (Appendix B, Figure 1). The first component, the wood frame, was attached to the headboard as well as the linear actuator. It was constructed out of three pieces of ¾" thick wood, arranged in a Z-shape configuration. The boards were connected by three screws on both the top and bottom corners, and additional metal supports were added to the bottom corner as well. In the future, strong Velcro straps would wrap around the

Figure 6:
Wood Frame

examination table and the top of the frame to anchor it in place.

*Headboard* - The headboard was attached to the top of the wood frame by two metal hinges. These hinges will interfere with fluoroscopic imaging, but this interference should be minimal because the imaging will be lateral. The headboard is also tapered 45° to allow +/- 45° of rotation from neutral.

Figure 7: Hinges between headboard and wooden frame.

*Linear Actuator* - The linear actuator, purchased from Firgelli Automations, supports up to 165lbs, has a 12" stroke length, and operates at a speed of 0.33"/sec with no load. To attach the actuator, the base piece of the actuator was bolted to a metal flange (1.25" by 4.5", 1/8" thick), which was in turn bolted to the base of the wood frame. The center of the actuator was mounted 5.9" from the bottom corner of the wood frame. This prevents the actuator from extending beyond +/- 45°, which could cause injury. Using a 9V and 12V battery source and no external loads, the full range of motion takes 50 and 28 seconds to complete respectively.

Figure 8: Base of linear actuator with metal flange.

Figure 9: Wooden roller guides.

*Roller Guide* - Lastly, a roller guide was attached to the top of the actuator. It was constructed by threading a metal cylinder ¼" in diameter through a hole in the top of the actuator. Two wooden wheels 2” in diameter were threaded through the cylinder on both sides. This allows the wheels to spin freely as the headboard rotates.

*Circuitry*

The circuit system was designed to provide power and control of the linear actuator from a remote location while ensuring safety for the user and the patient. To meet these needs, multiple components were included in the circuitry (Appendix B, Figure 2). Special mounting and configuration made these controls easy to use for both hospital staff and potentially patients. The following sections discuss these components as well as safety considerations taken into account in this design.

*Linear Actuator* - The main mechanism for this device is a linear actuator. This is a specialized type of motor, gear, and screw system. The motor drives gears in the base, which in turn drive a screw to extend or retract the shaft. Running the current in one direction extends the actuator, and running it the other way retracts it. When it reaches its range limits, the current continues to run through the motor even though there is no movement. The linear actuator remains in its current position if power to the motor is cut. Controls mentioned later ensure this is not a safety issue.

*Doctor’s Controls & Power Supply* - In order for the hospital staff to control this device from a remote location, the main cable extends out of the imaging room from the linear actuator and into the control room, approximately twenty five feet in length. This provides a reliable connection between the linear actuator and controls.

This control set includes a power switch and a toggle switch for the hospital staff to use during the procedure. These two switches are housed in a durable PVC box and mounted into the lid panel (Appendix B, Figure 4). This handheld casing makes operation and powering of device convenient for any hospital staff using the device.

Figure 10: Doctor's controls.

One of the controls is a double pole double throw (DPDT) momentary toggle switch. In this single switch there are three positions, (ON)-OFF-(ON). By specially wiring the DPDT switch, it can send current in two different directions, depending on the direction of toggle engagement. There are six terminals which make connections into the circuitry. Two of the terminals connect to a DC power source, and the other four terminals (really two pairs) send current between them in opposite directions. The leads from the linear actuator split and cross over these two pairs, so that current travels in one of two directions, depending on which direction the toggle is engaged. This switch is momentary, which means that the circuit is always open, except for when the toggle is engaged to control the linear actuator.

A power switch is housed with the toggle switch, also to be used by the doctor or hospital staff. Situated between the toggle switch and the power supply, this single pole single throw (SPST) switch can supply or cut power to the rest of the circuit. This switch is not momentary like the toggle switch; the circuit remains open or closed until the rocker switch is flipped. When in a closed ON position, the toggle switch is supplied with power, and can direct current to the linear actuator if engaged. The open OFF position cuts power, so there is no current for the toggle switch to direct.

The power source for the linear actuator is a 9 volt battery and roughly 200 milliamp-hours. It is a standard sized battery, and is conveniently housed within the doctor's controls, making replacement a simple task. As voltage decreases, the linear actuator speed does as well. A single battery lasts at least five full extensions and retractions when there is no load on the device. This is potentially wasteful, depending on the length of examination and number of patients served. Alternative power options are discussed later.

*Patient's Panic Button* - This device provides full control to the doctor to extend and flex the patient's neck during the fluoroscopic examination. While originally designed for obtunded patients, the circuitry incorporates another component to be used by conscious individuals undergoing examination. The patient could experience pain or discomfort during the procedure if the device begins to extend or flex their neck beyond his or her comfortable range of motion. Accordingly, a panic button has been incorporated (Appendix B, Figure 3).

Figure 11: Panic Button.

By flipping this rocker switch, power to the linear actuator is immediately cut, preventing further pain, and cuing the hospital staff to enter the imaging room and check with the patient. The hospital staff can not run the device unless the panic switch is closed. The circuitry of this switch is identical to the doctor's power switch. The linear actuator is ON while the circuit is closed, but turns OFF if this SPST switch opens the circuit. This switch effectively opens and closes the circuit in the main cable running from the linear actuator to the doctor's controls in the other room. An eight foot side arm of the main cable lets the patient hold this switch comfortably while lying on the table. The switch itself is housed in a modified pipe section, making it handheld and protected from damage if dropped.

*Safety Considerations* - This circuit configuration was chosen not only because it properly directs current through the linear actuator, but also for the extra measures of safety. The toggle switch reverts to an open circuit OFF position when not in use. Power usage is minimized by not keeping a closed circuit, and the life of the linear actuator is conserved because it isn't worn down from constantly running current through the motor. Running the linear actuator after it is fully retracted or extended for a prolonged period of time is potentially dangerous if the motor system is damaged. In addition to the doctor's controls, the patient has the option to engage an "emergency brake" on the system if he or she experiences pain. Altogether, this circuit takes extra precautions to ensure the safety of the patients, users, and the device itself.

**Conclusions and Ethical Considerations**

The current prototype meets most of the client requirements. It facilitates a full 45 degree range of motion from either side of the neutral position, allowing examination of the patient's cervical spine during both extension and flexion.

The current model is made out of wood, which is a low-mass attenuation material. The hinges are metal, which could interfere with the fluoroscopic imaging process. However, this is not of major concern, because most of the imaging during this particular procedure will be lateral. In the future, more appropriate materials, such as plastics, will be utilized to construct the frame and accessories. The metal hinges will be replaced by a flexible plastic hinge, which will not affect imaging.

In terms of circuitry, there is currently no feedback of what angle the device is positioned at going back to the hospital staff. By incorporating a protractor or goniometer with digital feedback, the staff can make better diagnoses of cervical disk health. Additionally, finding a more efficient and environmentally friendly power source is another ethical concern. Going through multiple batteries per procedure is wasteful, whereas a rechargeable battery or AC to DC power adapter is a better long-term solution. Finding a power source to deliver a specific steady voltage to give the correct speed would also be beneficial. Finally, converting this hardwired circuit to a wireless computerized system will improve the marketability and functionality of this device. It would minimize mess from tangled cords, automate extension and flexion using a computer program, and allow the staff to focus more on analyzing the imaging rather than operating the device.

The overarching goal is to create a functional device that is portable and easily used. The client would like to see this device patented; it is important that the device be adaptable to a commercial market.

Radiation is proven to be harmful to the body. Currently, hospital staff facilitate the fluoroscopy examination of the cervical spine by manually moving the patient’s neck during the procedure. This subjects the hospital staff to unnecessary radiation from the fluoroscopy machine and is unethical. The motorized prototype constructed will minimize the exposure to the staff by allowing them to control the procedure remotely.

The prototype constructed will require placing the patient’s neck on the hinge between the headboard and the fluoroscopy bed in order to facilitate extension and flexion. This may cause pinching, pain, or discomfort to the patient. To prevent this, a pad and head stabilizer will be attached to the headboard to ensure that the patient’s neck is not in direct contact with the hinge.

As discussed before, the circuit was designed while taking safety of the user, patient, and equipment into consideration, by incorporating various places to break the circuit to stop the device. Another ethical consideration made was how to power the device. The current battery system is temporary. Future development of this project will explore alternative power options that are more environmentally friendly. Further development and refinement of this design must occur before human testing with this device can be considered. In order to conform to ethical standards, IRB approval will be obtained before testing is conducted on human subjects.

**Appendix A**

# Product Design Specification

## Neck Extender & Flexor for Fluoroscopy Examination

**Team Members:**
Peter Strohm (Team Leader)
Vidhya Raju (Communicator)
Alison Boumeester (BSAC)
Susie Samreth (BWIG)

**Client:**
Victor Haughton, M.D.

**Last Update:** May 8th, 2007

**Problem Statement:** Our project involves creating a motorized neck positioner for a patient during fluoroscopy examination. The device must allow for extension and flexion of the head and cannot interfere with lateral radiographic imaging.

### Client Requirements:
- must extend and flex the patient's neck
- the prototype must not interfere with fluoroscopic imaging
- must be remote control operated
- the design must be universal to all fluoroscopic imaging systems

### Design Requirements:

***Physical and Operational Characteristics***

a. Performance requirements:
- 45° of extension and flexion from a horizontal resting position
- Rate of rotation must be constant (approximately 1°/second)
- Device should result in a natural rotating motion of the neck
- Motorized mechanism to facilitate movement
- Remote control operable from another room

b. Safety:
- Poses no risk of new or worsened neck injuries
- Doesn't impair or damage the fluoroscopy machine

c. Accuracy and Reliability:
- Reliably functions when operated by remote control
- Accurately simulate natural cervical vertebrae movement and rotation

d. Life in Service:
- Can handle at least ten patients per day
- Lifespan of at least two years
- Smaller components replaceable for maintenance

e. Shelf Life:
- Storable in room temperature sheltered environment
- Functional after extended periods of idle time
- Requires minimal maintenance

f. Operating Environment:
- Tolerate repeated exposure to x-rays from fluoroscopic imaging machine
- Withstand wear and tear from operation and movement by hospital staff
- Circuitry protected from damage due to humidity, fluid spills, temperature, or other adverse conditions

g. Ergonomics:
- Remotely operated (reduces X-ray exposure to staff)
- Easy to position patient on device

h. Size:
- Appropriately fitted to dimensions of fluoroscopy examination table
- Easily removable and storable
- Easy maintenance and modification

i. Weight:
- Less than 20lb, so it can be handled by staff
- Heavy enough to ensure stable operation

j. Materials:
- Metallic materials are not permissible in the area of examination (will interfere with X-ray signal

k. Aesthetics, Appearance, and Finish:
- Blend appropriately with existing hospital machinery (white)
- Smooth edges and texture to prevent injury during operation
- Can be sterilized between patients without damage to components

***Production Characteristics***

a. Quantity:
- One prototype, this semester
- Potential to mass produce if marketable

b. Target Product Cost:
- Less than $250 for prototype construction this semester
- At most $1000-$2000 for final product construction and material costs
- Final product market value of approximately $10,000

***Miscellaneous***

a. Customer:
- Accommodate average sized adult
- Patient may be unconscious or obtunded

b. Competition:
- Patent search revealed no similar devices
  Individual components of design may be patented

**Appendix B**

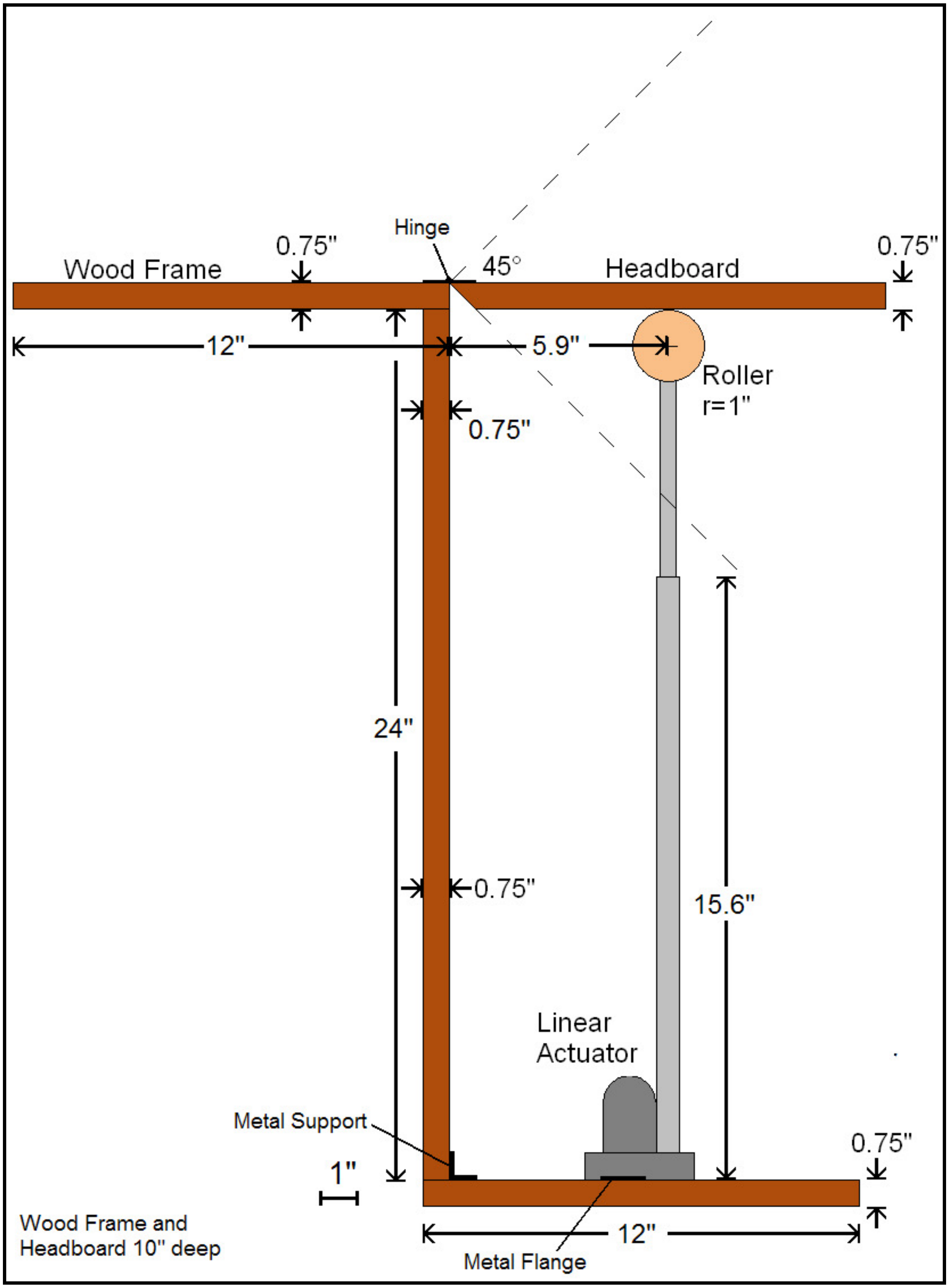
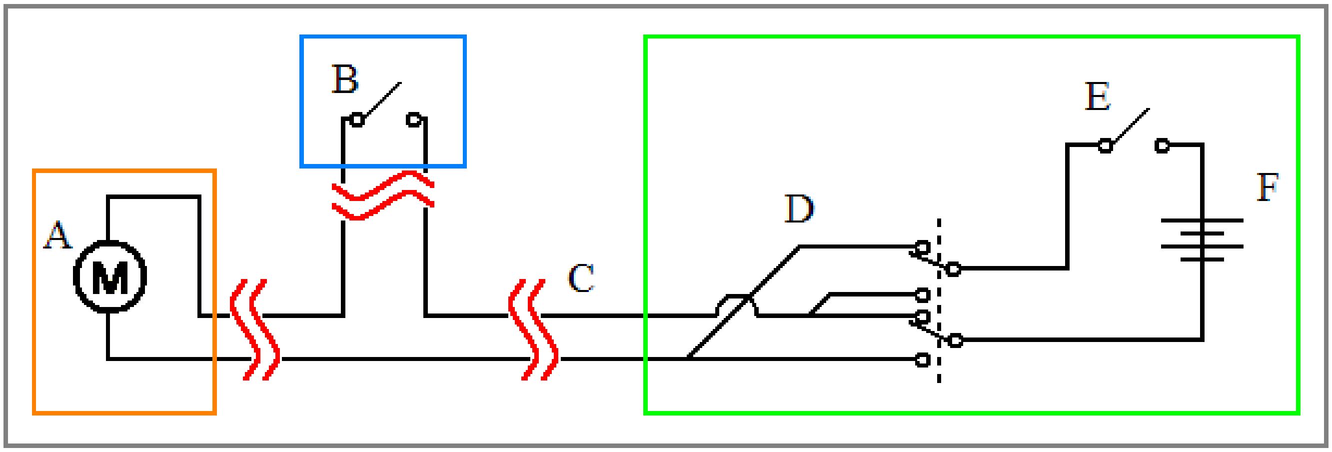



Figure 1: Scale Drawing of Frame.




A. Linear Actuator
 -12 V DC motor
B. Patient's Panic Button
 -SPST ON-OFF rocker switch
 -Rated for up to 12 V DC and 30 A
C. Main Cable (25' from linear actuator to doctor's controls)
 -25' span from linear actuator to doctor's controls
D. Doctor's Toggle Switch
 -DPDT (ON)-OFF-(ON) toggle switch
 -Rated for up to 12 V DC and 20 A
E. Power Switch
 -SPST ON-OFF rocker switch
 -Rated for up to 12 V DC and 30 A
F. Power Supply
 -Standard 9V battery

Figure 2: Schematic. Orange box represents linear actuator branch, blue represents panic button branch, and green represents the doctor's controls.

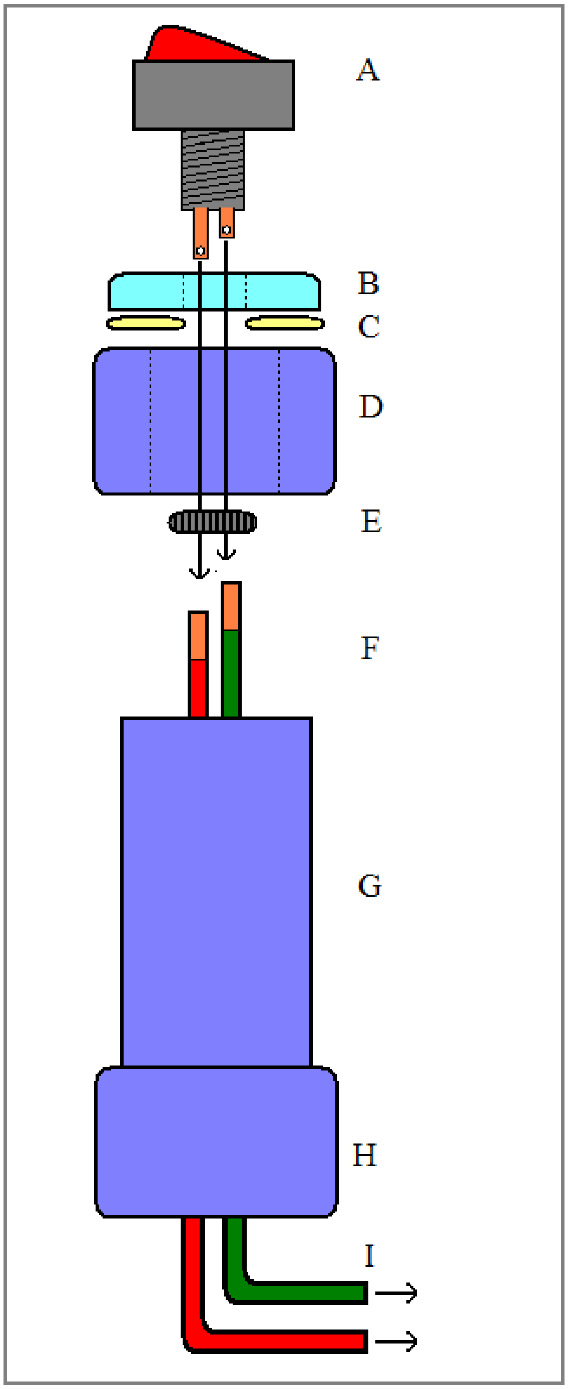



Figure 3: Exploded View of Panic Button Assembly

A. Panic Button
-SPST ON-OFF rocker switch
-Rated for 12 VDC and 30A
- ¼” hole mount

B. Plastic Disc
-Internal ring diameter of ¼”

C. Epoxy

D. Top pipe cap

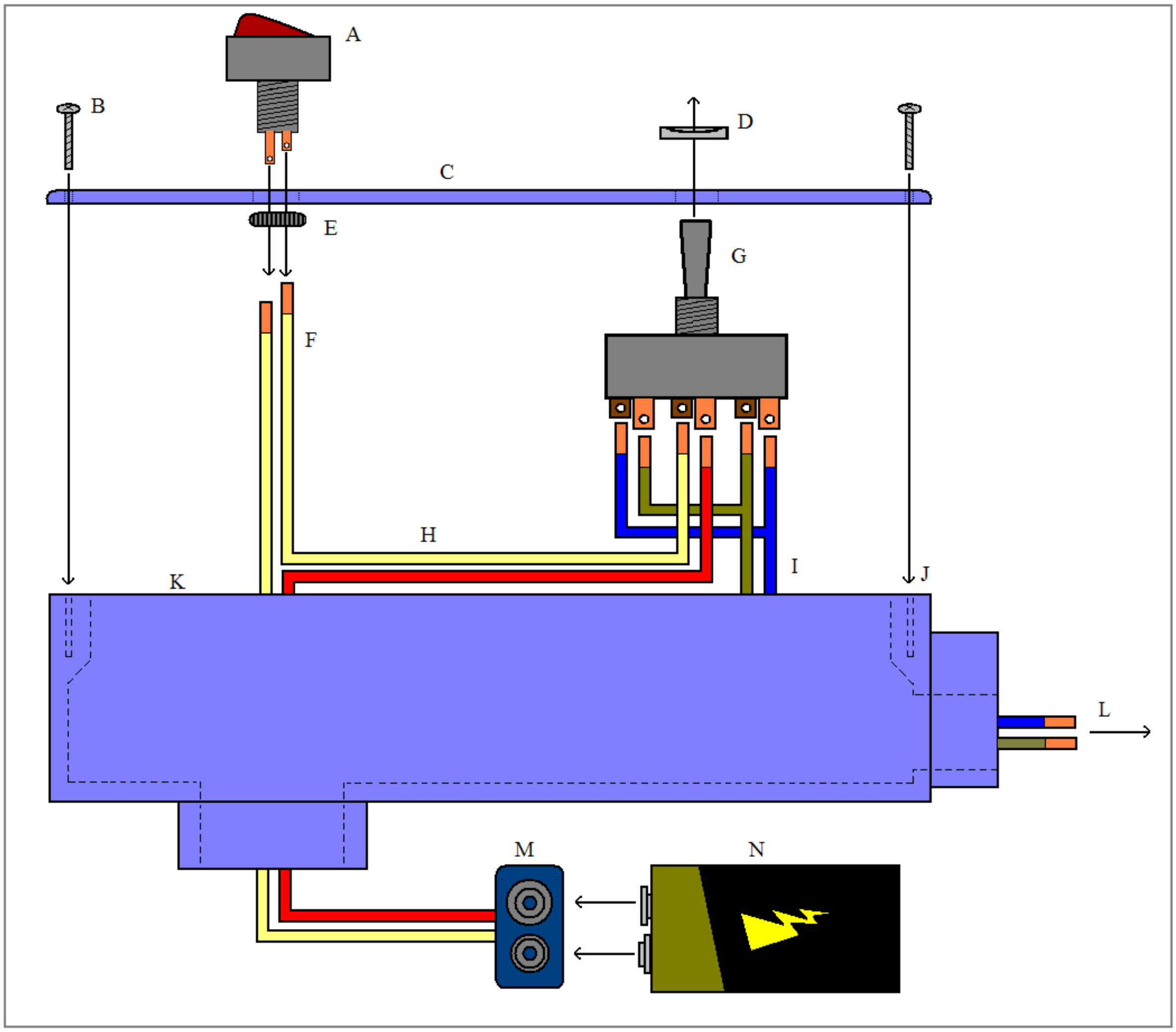
E. Nut
-Secures rocker switch to hole

F. Wire leads
-Soldered to terminals of switch

G. Pipe shaft

H. Bottom pipe cap

I. Wire leads
-Form 8’ tether to main cable




A. Power Switch
- SPST ON-OFF rocker switch
- Rated for 12 VDC and 30A
- ¼" hole mount

B. PVC Case Screw
C. PVC Case Lid
D. Toggle Switch Nut
E. Power Switch Nut
F. Wire Leads
- Soldered between toggle switch and battery

G. Toggle Switch
-DPDT momentary (ON)-OFF-(ON)
-Rated for 12VDC and 20A
- ¼" hole mount

H. Wire Leads
-From power switch and battery to toggle switch

I. Linear Actuator Lead Splitting
-Soldered to cross current path

J. PVC Case Screw Hole
K. PVC Case
L. Wire Leads
- From toggle switch to linear actuator

M. Battery Clip
-Fits standard 9V batteries

N. Power Source
-Standard 9V battery

Figure 4: Exploded View of Doctor's Control Assembly

**References**

Block, W. F. (2007). Fluoroscopy facility tour.

Eidelson, S. G. (2006). Cervical spine anatomy (neck). Retrieved March 1, 2007, from http://www.spineuniverse.com

Flexion and extension views of C-spine. (2007). Retrieved March 1, 2007, from http://www.wheelessonline.com

Fronczak, F. J. (2007). Design discussion.

Griffiths, H. J. (2001). The use of forced flexion/extension views in the obtunded trauma patient. Skeletal Radiology, 31(1), 587-591.

Padayachee, L. (2007). Cervical spine clearance in unconscious traumatic brain injury patients: Dynamic flexion-extension fluoroscopy versus computed tomography with three-dimensional reconstruction. The Journal of TRAUMA Injury, Infection, and Critical Care, 60(3), 03/02/2007. Retrieved March 2, 2007.

Ranallo, F. (2007). Fluoroscopy facility tour.

Saladin, K. (2005). Human Anatomy. McGraw Hill Publishers.

Schueler, B. A. (2000). General overview of fluoroscopic imaging. RadioGraphics, 20(4), 1115-1126. Retrieved March 2, 2007, from Web of Science database.

What is fluoroscopy? (2006). Retrieved March 1, 2007, from http://www.healthsystem.virginia.edu