Modification of Cauterizing Forceps for Microsurgery

University of Wisconsin – Madison
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Client:
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Abstract:

The problem that the group was presented with involved the modification of a device used during neurological microsurgery. The device used is similar to a standard forceps (Figure 1). When a foot pedal is depressed, activation of a radio frequency causes cauterization, but when released the radio frequency ceases. Cauterization results in the searing of tissue to stop blood flow. The foot pedal currently used is awkward and potentially dangerous due to the use of multiple foot pedals during surgery. A useful innovation would be a switch or button on or near the shaft of the forceps that would allow the surgeon to position the tips and cauterize in one single motion. A button or switch on the forceps is necessary to allow them to be used as a multipurpose tool during surgery. The forceps are used for both tissue manipulation and cauterization when needed. After carefully evaluating the needs of the client, a preliminary design was developed to satisfy these requirements and minimize cost.

Figure 1: Radio frequency cauterizing forceps (Valleylab, 2001).

Background Information:

Microsurgery involves the minute dissection or manipulation of living structures or tissue, such as those found in the brain. During microsurgery the surgeon's eyes are fixated in a microscope to enhance viewing of neurological components. This limits the surgeon's ability to make multiple movements. Modifications to the device are needed because the surgeon must look down during the operation to verify that the correct foot pedal is being depressed. This additional movement disrupts the concentration and progression of the surgery.

The surgical forceps function in both tissue manipulation and cauterization. In present instrumentation, the surgeon must continuously depress a foot pedal to allow cauterization. This causes a radio frequency, of varying amplitude and wavelength, to be sent to the tips of the forceps. This modulated radio frequency results in the cauterization, or closure, of the severed blood vessels.

Design Specification:

After meeting with the client, Dr. Behnam Badie, important design constraints and motivational factors for a new device were noted. The motivation behind modifying the presently used instrument is to allow cauterizing using one single motion versus the current foot pedal method. The foot pedal causes additional movement. It is inconvenient for the surgeon to look down during the operation to verify that the correct pedal is being depressed. Although the inconveniency of a foot pedal can be solved using a button on the forceps' shaft, Dr. Badie stressed that the motion to activate such a device must be natural. The use of the surgeon's other hand is not an option because it is necessary in the transfer of additional surgical equipment. Therefore, control of the button would be ideal if done with one hand, one finger, and with relatively no extra motion.

Several constraints were considered when developing the preliminary design. There were a total of five constraints, three focusing on the button and two on safety. The first was the height of the button. If the button is placed on the forceps, the surgeon's view must not be obstructed. Minimizing the height of the button as well as analyzing its placement on the forceps can solve this. The second constraint was the buttons width, which cannot exceed the width of its location. The third constraint is that the surgeon should not have to exert a large force on the button to cause cauterization. This is the main reason why a switch was decided against. To activate, a switch needs an x and y component of force. The x component will cause horizontal movement of the forceps, possibly changing the location of the forceps during an operation. The button, on the other hand, could be activated using only the y component of force. This would minimize any horizontal motion. Purchasing a button that needs a small amount of pressure to depress can also minimize the vertical motion. One constraint with respect to safety was the need for the forceps and button to be able to withstand sterilization techniques such as autoclaving. Autoclaving is the process of using pressurized steam to destroy microorganisms. Also, modifications made cannot have sharp edges that may puncture latex gloves during surgery.

The literature search was futile. The only available articles found pertained to how forceps can be used during surgery, not the specifications of the forceps. Therefore, help was sought help from Professor Burke O'Neal. Professor O'Neal is an expert with electronics and gave insight on how to wire a button placed on the shaft of the forceps. Three wires would be necessary: one for the electrical input, another for the switch, and a third for the electrical output. Professor O'Neal also made clear that the button itself was not something that could be easily purchased. Buttons used in medical instrumentation must be manufactured to a high degree of accuracy.

Possible Solutions:

General Design

Due to the many specifications from the client, one main design was developed with several variations. The main design consists of forceps that have an easily depressible "bubble" button for the activation of cauterization. This type of button was chosen because it has a protective "insulation" material. The protective material would cover any cracks or edges where debris or liquids could settle, causing malfunction. The flexible insulation material would also serve as protection for the electrical components. The button would also be brightly colored to indicate its exact location. The button would work similarly to the foot pedal in that when depressed, cauterizing would take place, and upon release, cauterizing would immediately stop.

Idea #1 ("Bubble" button on shaft of forceps – Figure 2)

In this design, the button would be placed on the top edge of the forceps, approximately where the thumb is placed when squeezing the forceps together. The wiring for the button would include Professor O'Neal's suggestion for three wires, which would be placed in a thin groove down the inner side of the forceps. The groove would be used to make the forceps feel similar to present models. It would prevent the wires from altering the surface of the original forceps. This design requires an insulation material to hold the wires within the groove. Insulation material is found on many modern forceps.

Advantages: This design meets the requirements suggested by Dr. Badie in that the button is within the range of natural motion of the hand. In this location, the button is easily depressed in one motion using the index finger.
Disadvantages: This design would only be appropriate for a left-handed or right-handed surgeon depending on which arm of the forceps the button is placed. This causes the need for two forceps in each operating room, which increases the cost for the hospital. A second disadvantage would be that the button width would need to be very small to fit on the arm of forceps. This may cause additional problems when adhering the button to the shaft.

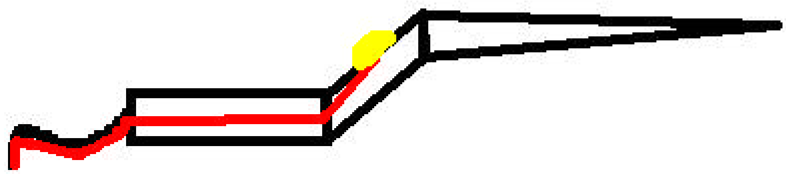

Figure 2: Idea #1, placement of the button on the top edge of the shaft.

Idea #2 ("Bubble" button on a fixated platform - Figure 3)
In this design, the button would be placed on a platform between the arms of the forceps. The platform would be fixated to one arm and span a distance no larger than the total distance between the two arms of the forceps in the closed position. The wiring of this button is the same as design #1.

Advantages: This design meets the requirements suggested by Dr. Badie in that the button is within the range of natural motion of the hand. In this location, the button is easily depressed in one motion using the index finger. This design would enable either left-handed or right-handed surgeons to use the same forceps, decreasing the cost from two forceps to one for each operating room.
Disadvantages: One disadvantage to this design is that the platform would need to be precisely constructed to minimize problems while in use. One problem that may occur would be if the platform were to bend downward, the forceps would have a restricted range of motion making them non-functional. A second problem arises if the platform were to puncture or pinch the surgeon's latex gloves during surgery causing a safety hazard. In addition to these structural disadvantages, there would also be a cost disadvantage. To build this design well, the forceps would need to be re-tooled to secure the platform. As a result, this would increase the cost to manufacture them, therefore increasing the cost for the hospital. To reduce the cost the platform could be soldered to the arm, but the strength at this connection could be an issue.

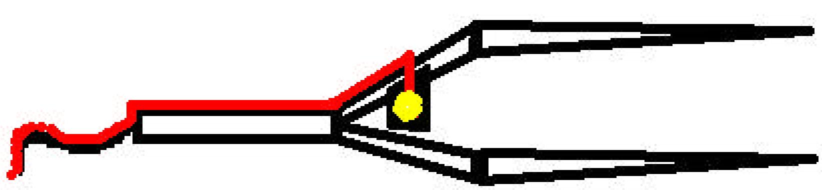

Figure 3: Idea #2, placement of the button on a platform between the arms of the forceps.

Idea #3 ("Bubble" button on a removable platform - Figure 4)
In this design, the button would be placed on a removable platform that can be temporarily fixated to the shaft of the forceps using a simple clamping device. The clamping device includes the platform secured to two clips that will wrap around the shaft of the forceps. The wiring for the button is similar to that used in designs #1 and #2. The difference for this design is that the wires would be wrapped into a single cable, which would be placed along the top edge of the shaft of the forceps. The wires would be temporarily fixated to the cable used to transport radio frequency to the forceps.

Advantages: One of the major benefits of this design is that this removable platform can be used on existing forceps, decreasing the cost. Instead of buying a redesigned forceps that integrates a button into its original design, a platform adapter could be purchased instead. The platform could be clamped to the shaft of the forceps using a small nut and bolt to tighten the sides of the platform clips. This design meets the requirements suggested by Dr. Badie in that the button is within the range of natural motion of the hand. In this location, the button is easily depressed in one motion using the index finger. This design would enable either left-handed or right-handed surgeons to use the same forceps, eliminating the cost of any additional forceps for the operating rooms.
Disadvantages: There are two disadvantages to this design, but both can most likely be resolved. The first involves the temporary fixation of the platform. If the platform is not secured, there could be movement of the platform during surgery. Depending on this movement, the surgeon may need to reconfigure the device causing a delay in the surgery and a loss of concentration. The second disadvantage involves the wiring for the button. In this design, the wires are simply placed on the top edge of the forceps allowing the wires to freely move. The wire may become tangled in other equipment during surgery.

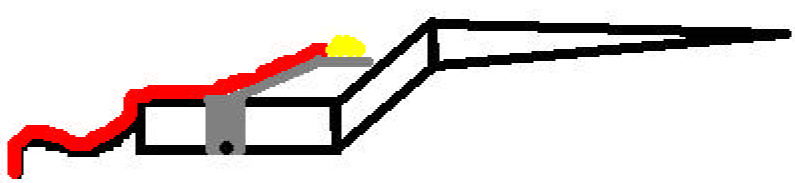

Figure #4: Idea #3, placement of the button on a removable platform.

Chosen Design

The design chosen that met most of the requirements suggested by Dr. Badie and was the most cost effective was the "bubble" button on a removable platform (Idea #3). One of the design requirements concerned the height and width of the button. In this design, the height can be adjusted so the platform and button are outside of the necessary range of site needed by the surgeon.

The width of the button is only limited to the size of the platform and not the width of the forceps. With the use of a “bubble” button, the surgeon is able to cauterize with one single motion without using excessive force. The force needed to depress the button can be accommodated for at the time of button purchase. Other design requirements involved safety while using the modified forceps. The first safety requirement was that the forceps and button must be able to withstand sterilization techniques such as autoclaving. Purchasing materials that can withstand sterilization for the construction of the design can solve this. The second safety condition was that the modifications made should not have sharp edges that may puncture latex gloves. This design can be adjusted so the platform and fixation device have only rounded edges. A casing, containing a fixated nut and the exposed end of a bolt, could protect the surgeon’s gloves during surgery. The bolt would be tightened into the fixated nut leaving it flush with the clip surface (Figure 5).

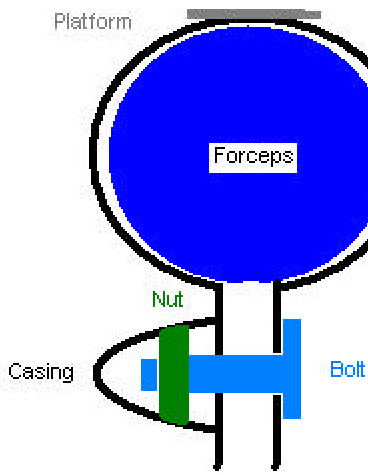

Figure 5: Cross section view of the clip with a protective casing for the end of the bolt.

Conclusion:

The “bubble” button on a removable platform design most adequately satisfies the client’s needs. It allows single motion cauterizing using a button instead of the currently used foot pedal. This design is most cost effective because it allows both left-handed and right-handed use without the need to purchase additional forceps.

The design chosen is based on the knowledge gained thus far, which is limited by the accessibility of the forceps. A prototype of the forceps is necessary to completely understand how and if the chosen design is appropriate. It is understood that alterations to the design may be needed after further analysis of the instrument.

Appendix:

References

O'Neal, Burke, University of Wisconsin Instrument Innovator Researcher, (Madison: 28 September 2001), In-person interview.

Valleylab, www.valleylab.com (2001).

Product Design Specification (PDS)

October 19, 2001

Crystal Marshek
Luke Harris

Title: Finger Switch for Neurosurgical Electrocautery Forceps

Function: Radio frequency activation finger switch on or near the shaft of cauterizing forceps to replace the current foot pedal.

Client requirements:

- Button will not obstruct view down shaft
- Be reusable (i.e. – able to be sterilized)
- Light finger pressure activation
- Located on forceps in a position where one finger can activate without changing the position of the hand on forceps
- Depressible button preferred over a sliding switch design

Design Requirements:

1. Physical and Operational Characteristics:
    a. Performance Requirements –
        The device must function both as general surgical forceps and as a blood vessel cauterizing tool. The surgeon must be able to grasp the device in one hand and easily manipulate it with as little as a thumb and an opposing finger. This manipulation would include cutting, grasping, pulling, and separating tissues and blood vessels. The cauterizing function of the device is to involve heating of the tips of the forceps using high frequency electric current ranging from 300 kHz to 500 kHz. This heat will allow the surgeon to cauterize, or close, blood vessels as they are severed, thus minimizing blood loss. The high frequency current is to be activated via a switch or button that can be depressed with one of the free fingers of the hand in which the device is held. The device must be capable of both extended and interrupted (i.e., on-off) use on a daily basis. A load resistance of 100 ohms is expected, based on typical values.
    b. Safety –
        It is essential that the surgeon is able to instantly activate and deactivate the current in the forceps, and care must be

taken to minimize the chances of accidental activation. As the device's operation involves current flow and high temperatures, sufficient thermal and electrical insulation must be provided to prevent electrocution and/or unwanted burning of tissues. The device also must be designed in such a way that no features hinder the surgeon's ability to operate on the patient as necessary.

c. Accuracy and Reliability –

 The device must be capable of repeated heating to a temperature sufficient for cauterization. This level of precision requires a power generator that consistently produces frequencies between 300 and 500 kHz.

d. Life in Service –

 The surgeon must be able to rely on this device to work as Desired throughout the day, every day, for several years. Use of the forceps will be sporadic, lasting anywhere from a few seconds to several hours.

e. Shelf Life –
    - Store at room temperature (68°±10°F)

f. Operating Environment –
    - Possible exposure to blood, water, acids/bases, and dust
    - Operation temperature range: 65°F to 90°F
    - Must be able to withstand autoclaving procedures (heat/vibrations)
    - Used by: Surgeons

g. Ergonomics –
    - Switch/button on tweezers must not obstruct view during surgery
    - Switch/button must be completely protected/insulated from liquids or debris to prevent malfunction
    - Switch/button must be easy to function
    - Switch/button should be located in a position such that it is easily accessible
    - When activating the switch/button, the surgeon should not have to introduce an awkward motion. It should feel "natural."

h. Size –
    - Tweezers:
        - Length: 10.2cm to 22.2cm
        - Tip: .7mm to 1.5mm
    - Switch/Button
        - Length: 1.0cm
        - Width: .5cm to 1.0cm
        - Height: .5cm

i. Weight –
The probe should be light enough so the surgeon can work hours without trouble. It should also be light enough so that there exists no problem such as shakiness or sudden movements when cauterizing

j. Materials –
Instrument must be of high heat resistance material. It should be easily cleaned and sterilized. The material for button should be made up of some type of almost frictionless plastic against rubber latex gloves.

k. Aesthetics, Appearance and Finish –
Probe is steel in color. The shape is the same as usual with the mid point of the instrument angling and curving up with the extensions slightly angling back down into the surgeon's line of view again. The total length of the probe is approximately 8 inches long.

2. <u>Production Characteristics:</u>
   a. Quantity –
      - One working prototype
   b. Target Product Cost –
      - Our cost should be approximately $30 (button, wire, platform (if necessary)). Similar instruments run between $250 and $350 each. With our addition, the tweezers should be slightly more expensive.

3. <u>Miscellaneous:</u>
   a. Standard and Specifications –
   b. Customer –
      - Switch will not obstruct view down shaft
      - Be reusable (i.e. – able to be sterilized)
      - Light finger pressure activation
      - Located on forceps in a position where a finger can activate without changing hand position on forceps
      - Depressible button preferred over a sliding switch design
      - Should be "on" only when button is depressed
      - No wires should be exposed
      - Should not inhibit normal use of forceps
   c. Patient Related Concerns –
      - Sterilization between uses
   d. Competition –
      - No patents were found