BME 200/300: Biomedical Engineering Design

Umbilical Cord Model for Umbilical Vein Catheterization Training

– The Umbilical Team –

PROGRESS REPORT 9

Friday, November 9 to Thursday, November 15, 2007

Clients:

Dr. Julie Kessel
Department of Pediatrics
608-417-6236 (office)
608-265-7000 (pager; code: 6318)
jmkessel@pediatrics.wisc.edu
jmkessel@facstaff.wisc.edu

Sharon Blohowiak
Neonatal research laboratory
608- 417-5780/ sblohowiak@pediatrics.wisc.edu

Advisor:

Professor Brenda Ogle
Department of Biomedical Engineering
2144 Engineering Centers Building
608-265-8267 / ogle@wisc.edu

Team Members:

Ann Sagstetter
Team Leader (Leadership & Progress Reports)
507-951-8735 / sagstetter@wisc.edu

Padraic Casserly
Team Leader (Finance and Time Contributions)
507-269-9901 / pcasserly@wisc.edu

Songyu Ng (aka Kelvin)
Communicator
608-770-7855 / sng2@wisc.edu

Angwei Law
BSAC
310-804-7028 / alaw@wisc.edu

Timothy Balgemann
BWIG
630-903-9811 / balgemann@wisc.edu

Initial Problem Statement:

The American Academy of Pediatrics Neonatal Resuscitation Program (NRP) is required training for thousands of physicians and medical staff who attend the delivery of newborns. Placement of an intravenous catheter in the umbilical vein of the cord stump in a distressed newborn is one way to provide life saving medication and is a skill that is essential to the NRP course. Hands-on training in the placement of an umbilical venous catheter has received increased attention and emphasis since the 2005 update of the NRP course. Currently, two models for hands-on training are available. Some companies make newborn models for CPR that also have artificial umbilical cords (ex Laerdol). These models appear to inadequately mimic placement in a real cord and are very expensive. Alternatively, the American Academy of Pediatrics recommends using sections of an umbilical cord obtained after delivery. The cord section is placed in a glass baby bottle with part of the nipple cut off so the cord extends about 1/2 an inch from the top of the nipple. While this model has the advantage of using a real cord, the cord is secured poorly and thus does not adequately mimic placement in a newborn. My design idea is to make a support for real umbilical cords that would more closely mimic the umbilical stump of a newborn. The model could be made out of a material that might mimic the abdominal wall, such as ballistic grade gel, and might perhaps have two halves that clamp around a section of real cord. The model could mimic the curves of the umbilical vein after it enters the body, making placement more realistic. Ultimately, this model, which would best be quite inexpensive and disposable, could be marketed to the over 25,000 individuals in the US who teach NRP and would likely represent a vast improvement over the "baby bottle" model.

Revised Problem Statement

To construct a model optimized for use in the umbilical vein catheterization training program, a suitable method is to be devised to firmly hold a fresh umbilical cord in place. In addition, the model needs to accurately mimic the external texture and internal structure of the human neonatal abdomen.

Last Week's Experiments:

Cord-in-Gel Approach:
1a) increasing humidity of cords' local environment by fixing them in an airtight container with a humidifier
1b) finding out whether gel concentration is a major factor in cord coiling; if so, determine the gel concentration that minimizes coiling
1c) coating the Playtex liner with sandpaper to increase adhesion between the hardened gel and the inner wall
1d) filling the gel solution to the brim of the Playtex liner so that the lip of the Playtex liner is preserved to prevent slipping in another Playtex liner
1e) cutting a hole at the bottom of the liner so that the cord can pass through and be straightened during gel fixing
1f) tying a metal piece (eg. wire) to the bottom of the cord and place the gel containers on a magnetic board during fixing to straighten the cords
1g) using a bigger foam support to re-direct pressure of the trainee's hands from the gel column to the foam support
1h) sealing the Playtex liner with cord to the Playtex liner with water to prevent seepage

Sphygmometer Approach:
2a) design and construct a cuff that suits our needs (eg. spiral air tube, inflatable ring)
2b) adhering the current cuff to the inner wall of a Playtex liner

Summary of Accomplishments:

Experiment 1: Tensile Test

Purpose: Tensile tests were performed on the cord/gel model to quantify the stability of the cord in the gel under varying concentrations of gel.

Methods: A newton meter was obtained and a string was tied to the spring gauge. The other end of the string was tied around the circumference of the cord sticking out of the gel. The cord/gel unit was then pulled slowly and the force was read on the Newton meter at the time point when the cord fully was expelled from the gel.

Results:

The data collected demonstrated no immediate correlation between concentration and applied force (Figure 1); however it was determined that there could be a dependence between the length and diameters of the cord and the force applied at varying concentrations.

Figure 1: The raw data correlating with this experiment.

Sample	Concentration (units)	Force Applied (N)	Length of cord (m)	D_1 (mm)	D2 (mm)
1	1.5	19.6	0.105	10.87	7.68
2	2	15.68	.081	13.42	11.73
3	2.5	15.68	.104	11.34	9.06

Future Work: With this data, we need to correct for length and diameter and compute the stress/strain curves for further data analysis.

Experiment 2: Gel-Cord Stabilization Using Playtex Slip

Purpose: Catheterize Playtex slip in a concentration of 2.5 units (same as the last Playtex catheterization in Week 8 Progress Report), but with the addition of sand paper grip applied to the interior of the playtex slip before gel insertion. The purpose of the sand paper is to increase the surface area of the slip, so that the gel will not break away from the slip during catheterization.

Methods: Sand paper with a sticky backing was applied to the wall of the slip. Cord was inserted into slip. Gel was poured. The system was placed in a sealed plastic bag and stored at 4°C on Thursday. Friday afternoon (24 hours later) the cord underwent catheterization training protocol.

Results: The umbilical cord was not able to be functionally catheterized in the model; however, it is unsure whether the cord itself that was the problem. It was noted during the catheterization process that the cord started slipping away from the gel. HOWEVER, the gel remained in absolute contact with the sand paper and the Playtex slip, which was the purpose of this experiment.

Future Work: The cord-gel slipping needs to be addressed for this model to be pursued; however, we have stabilized the gel to the slip. Also, this cord was not able to be successfully catheterized; however, we think it's probably the integrity of the cord that was in question, which would result in difficulty catheterization, no matter how good the model is. Thus, we need to test cord preservation, to find the absolute best preservation method for any catheterization training. Last week, none of the cords were concealed in a sealed container overnight, leading to a slight drying of the cords. This could have contributed to the easy catheterization exhibited in week 8. This coming week, we'll focus on which preservation method is best, and then test our models using those cords.

Experiment 3: Cuff model

Purpose: Catheterize the umbilical vein using a small blood pressure cuff with adjusted reservoir container to fit the cuff.

Methods: A day-old cord was placed in a sealed plastic bag and stored at 4°C on Thursday. Friday afternoon (24 hours later) the cord underwent catheterization training protocol.

Results: The umbilical cord was not able to be functionally catheterized in the model; however, it is unsure whether the cord itself that was the problem (could be the preservation technique). The cuff did hold the cord very nicely, but towards the end, the cord had a tendency to slip slightly. We used a syringe and bivalve to inflate the cuff and maintain constant pressure to stabilize the cord. This worked very well and was very user friendly.

Future Work: The cuff did triangulate when filled, which allowed a three point pressure on the cord, which might be the cause for some slipping during the catheterization training. This might be fixed by inflating continuously (in a circular fashion) avoiding crimps or creases in the cuff. To do this, we're trying to create a smaller cuff, which will allow the air to flow more symmetrically about the cuff. We also need to test the quality of the cords via different preparation mechanisms, which might alleviate a lot of the catheterization problems that we're experiencing.

<u>This Week's Goals:</u>

<u>Gel Approach</u>

1) Calculations to relate gel concentration versus force needed to remove cord from gel - Friday
2) Experiments to determine if cold drying will increase the success of catheterization - Thursday & Friday

<u>Sphygmometer Approach</u>

3) Shopping for better alternatives to substitute current blood pressure cuff - Weekend
4) Experiments to miniaturize air cushion of baby oxygen mask (a continuous circular cuff) - Friday

EXPERIMENT (Setup/Testing: Thursday, Further Testing: Friday)-

Purpose: To find the optimal cord preservation technique.

Materials:
a) 6 intact, full-length, fresh umbilical cords on Thursday, with the proximal end marked
b) 2 5-F catheters on Thursday and 2 5-F catheters on Friday
c) 1 mass balance on Thursday and Friday

Methods:
We are not certain if (a) is possible, but we sincerely hope that it can be done to substantiate the integrity of our results. The rationale behind this is that we intend to find out if the success of catherization can be improved by drying the cords in the fridge, and if the success of catheterization depends on the distance from the proximal end of the cord. To do so, we will leave 2 cords in open air in the fridge and 2 cords in airtight bags in the fridge, both overnight on Thursday. Prior to this, we will section each cord into 3 or 4 sections and label them according to their distances from the proximal end. On Friday, we will catheterize all 6 or 8 sections and obtain the success rate. The remaining 2 cords will be sectioned and catheterized on Thursday under fresh conditions. These serve as a control for comparison with the other 2 "treatments".

Difficulties:

There have been no difficulties to date.

Activities:

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Ann Sagstetter:
Team Meetings – 4 hours
Gel/Cuff experiment preparations -4 hours
Progress Report – 1.5 hours
Total: 9.5 hours

Padraic Casserly:
Team Meetings – 4 hours
Literature Research - .5 hours
Finance/Activities- 1 hour
Total: 5.5 hours

Songyu Ng:
Team Meetings -4 hours
Scheduling & Communications – 1 hour
Literature Research – 0.5 hours
Total: 5.5 hours

Angwei Law:
Team Meetings -- 4 hours
Literature Research -- 2 hours
BSAC Meeting -- 1 hour
Total : 7 hours

Tim Baglemann:
Team Meetings – 4 hours
Cuff experimental preparations – 4 hours
Total: 8 hours

Projected Time Line:

September 21: Form teams
Select project
Meet with client
Literature Search
September 28: Finish required tissue training modules
Write PDS
Post preliminary PDS on web site
Start Brainstorming
October 5: Brainstorm
Work out possible designs
Design Matrix
October 12: Choose Design
Start ordering materials if needed
Prepare oral presentation
October 19: Oral Presentation
Put PowerPoint presentation on team web site by 10:00 am
Hand in written report at time of presentation
October 26: Commence prototype design
November 2-9: Designing process finish
Stabilization testing, evaluation, and adjustments
November 16-30: Final prototype construction, Final tests
Begin final paper and poster preparations
December 7: Poster presentation
December 12: Written report due.

KEY: Green Highlight: Completed
Purple Highlight: Completed by Tonight
Yellow Highlight: In progress
Blue Highlight: Goal for coming week

Finances:

Dorn True Value Hardware

5pk Med Alo Sandpaper: 2.49
2pk 2x4 HD Velcro Strip: 2.99
Mp 1-1/2 x 15 in Plastic Tub: 3.99
5/8 x 7/8 in Plastic Tubing: 1.58
5/16 x ½ in Plastic Tubing: 1.59
Sub-Total: $14.21

The Home Depot

Adhesive Grip Spray Paint: 4.92
Rubber Gloves: 3.97
Epoxy Glue: 2.97
6x24 Strips: 5.97
Grade 36 Sandpaper: 2.17
Sub-Total: $24.23

Wal-Mart

Three-Pack Foam Balls: 3.54
2.00 Yards sq. Vinyl: 4.88
Sub-Total: $8.88

Capital Centre Foods

Knox Gelatin pack x 8: 12.72
Ziploc Storage: 3.39
Pam: 3.29
Sub-Total: $19.59

Total: $ 66.91

Note: ***The client contributed $60.00 on October 12.***
The client contributed $60.00 on November 2.