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USING PERCENTILE MATCHING TO SIMULATE LABOR PROGRESSION AND THE EFFECT OF LABOR DURATION ON BIRTH COMPLICATIONS

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ABSTRACT

Of the nearly 4 million births that occur each year in the U.S., almost 1 in 3 is a cesarean delivery. Due to the various increased risks associated with cesarean sections (C-sections) and the potential major complications in subsequent pregnancies, a re-evaluation of the C-section rate has been a topic of major concern for patients and health care providers. To evaluate the current C-section rate due to a "failure-to-progress" diagnosis, we implement a percentile matching procedure to derive labor progression times needed to replicate the delivery process in a discrete event simulation for women undergoing a trial of labor. The goals are to: (1) model the natural progression of labor in absence of C-sections, (2) determine the underlying rules responsible for the current rate of cesarean deliveries due to a "failure-to-progress" diagnosis, and (3) develop stopping rules that reduce the number of cesarean deliveries and the rate of complications.

1 INTRODUCTION

For many years the guidelines surrounding the amount of time spent in labor were governed by the Friedman Curve which was established in 1954 by obstetrician Emanuel Friedman. Friedman described abnormal labor progression as cervical dilation of less than 1.2 cm per hour for nulliparous women (women giving birth for the first time) and cervical dilation less than 1.5 cm per hour for multiparous women (women who have previously given birth). He further defined no change in dilation for more than two hours as labor arrest. The goal of the Friedman Curve was to provide guidance regarding an appropriate delivery time frame that would result in the best outcomes. A C-section performed due to abnormal labor progression or the perceived notion that a woman will not reach full dilation in a time period associated with optimal health outcomes is often diagnosed as "failure-to-progress." However, due to changes in the delivery process and changes in the demographics of laboring women, a re-evaluation of the use of the Friedman Curve guidelines is needed.

Using a percentile matching procedure to simulate labor times, we develop two simulation models that model labor progression in order to inform policies regarding the length of time a woman can be allowed to labor. The first model, Model 1, characterizes the natural progression of labor. This model seeks to understand the length of time a woman may labor if no interventions or C-sections are introduced. The second model, Model 2 is similar to the first model; however, upon completion of each dilation state, the total time in that dilation state is evaluated to determine whether the patient should undergo a C-section based on a defined stopping criterion. That is, if a stopping rule of two hours (i.e., result of Friedman Curve) is implemented and a patient requires 3.6 hours to dilate from 4 cm to 5 cm, then she would be given a C-section at 4 cm. If she had progressed from 4 cm within two hours, she would continue to labor and proceed to 5 cm.

2 DATA DESCRIPTION

Data for the models were derived from literature where current labor progression patterns were evaluated for three different patient types: (1) patients who had an induction of labor, (2) patients who had an augmented labor and (3) patients who had a spontaneous labor. To account for the complications that may arise based on time in labor, we used literature to derive probability distributions. Each patient was randomly assigned a probability of complications as a function of the total time spent in labor.

3 PERCENTILE MATCHING

In order to provide each patient type with a random labor progression (i.e., estimation of the probability distribution of labor progression) for each dilation state, we use a percentile matching procedure assuming a log normal distribution. The goal of the percentile matching procedure is to find the exact (or a close approximation) of the log normal distribution that provides the same median, 5th and 95th percentile values provided in the literature. Due to the limitation of not knowing exactly when a cervical dilation change occurs, each literature source reported the use of interval-censored regression to estimate the percentiles for the duration of labor (Vahratian, Zhang, Hasling, Troendle, Klebanoff, and Thorp 2004). Interval-censoring is used when the time of an event is not known; however, it is known that the event occurred within a certain interval of time (i.e., the minimum and maximum possible times). By matching percentiles, we are then able to fit log normal distributions for each dilation state and each patient type.

4 RESULTS

The results of Model 1 showed the average time in system, which we define as the length of active labor from 3 cm to vaginal delivery, was 8.93 ± 0.03 hours. The minimum and maximum times were 1.10 ± 0.12 hours and 104.46 ± 25.34 hours, respectively. Having such an estimate can inform the definition of policies for determining appropriate times to end a trial of labor for those patients considered "failure-to-progress."

Using Model 2, we were able to understand the effect of waiting before deciding a patient has failed to progress and a C-section is necessary using a stopping criterion of 2 hrs, 3 hrs, etc. for each dilation state. The comparison of rates and number of complications are displayed in Table 1. The results show an inverse relationship between the number of C-sections and the number of complications. The table show that as the stopping rules increase in length, the marginal benefit (and loss) is minimal. That is, the percentage decrease (and percentage increase) decreases as the stopping rules increase.

Table 1: The marginal percentage of decrease for C-section rates and marginal percentage increase for expected number of complication as a function of changes in the stopping rule.

Number of Hours Allowed to Labor	Percentage of C-sections	Rate of Decrease	Expected Number of Complications	Rate of Increase
2	0.70		156.33	
3	0.48	-31.43%	268.90	72.01%
4	0.33	-30.83%	346.25	28.77%
5	0.23	-29.54%	394.17	13.84%
6	0.17	-27.37%	430.24	9.15%
7	0.13	-24.04%	453.06	5.30%

REFERENCES

Vahratian, A., J. Zhang, J. Hasling, J. F. Troendle, M. a. Klebanoff, and J. M. Thorp. 2004, July. "The effect of early epidural versus early intravenous analgesia use on labor progression: a natural experiment.". *American journal of obstetrics and gynecology* 191 (1): 259–65.