Vaginal Birth After Cesarean Section (VBAC) Model using Fuzzy Analytic Hierarch Process

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ABSTRACT

Background: There is an even more pressing need to address the issue of vaginal birth after cesarean section (VBAC), as an increase of cesarean deliveries (CDs) has been noticed. This increase however was temporarily overturned during the period 1989-1996, when some researchers tried to manifest the advantages of trial of labor after cesarean (TOLAC). Increased VBACs though raised the issue of scar ruptures, causing fear to women and guiding them once again towards the choice of cesarean deliveries. The numbers of Cesarean Sections (CS) still increase, despite the initiatives promoted by the World Health Organization (WHO) to reduce the rates of CS. Objective: This research aims to construct two fuzzy models, the Fuzzy vaginal birth after cesarean (VBAC) model and the fuzzy CS model in order to assess the medical profile of pregnant women and to suggest the most suitable type of delivery. Methods: A preliminary set of factors that affect VBAC or CS was identified after a comprehensive literature review. The final set of factors was used to develop a questionnaire and collect data regarding the identified factors, through a series of semi structured interviews with 29 highly experienced obstetricians. The Fuzzy Analytic Hierarchy Process (FAHP) method is utilized to develop the fuzzy VBAC and the fuzzy CS multicriteria decision models. Results: A set of 36 factors in total are identified as important to consider when judging the most suitable type of delivery. Results show that a subset of 27 factors support the decision to adopt CS, with top 5 most significant to be: vaginal delivery is contraindicated, prior uterine rupture, uterine incision, extensive transfundal uterine surgery and desire for sterilization at the time of delivery. A subset of 9 factors positively affects the decision towards VBAC. The top 5 of the most important factors that positively affect the decisions to adopt VBAC are: Maternal request for VBAC, Mother’s personal values/preferences, Previous bladder injury, Health care providers recommendations, Family obligations, and Prior VBAC after CS. Conclusions: The proposed approach addresses the multi-dimensional nature of judging the most appropriate type of delivery. By utilizing fuzzy logic analysis obstetricians and midwives are allowed to express their expertise and their intuition in a sound methodological approach to assess cases of pregnant women and suggest a valid route of intrapartum care.

Keywords: VBAC, Cesarean Section, Fuzzy multi-criteria analysis, decision making.

1. BACKGROUND

There is an even more pressing need to address the issue of vaginal birth after cesarean section (VBAC), as an increase of cesarean deliveries (CDs) has been noticed (1). This increase however was temporarily overturned during the period 1989-1996, when some researchers tried to manifest the advantages of trial of labor after cesarean (TOLAC) (2-4). Increased VBACs though raised the issue of scar ruptures, causing fear to women and guiding them once again towards the choice of cesarean deliveries (5). In contrast to some people’s beliefs however, the augmented amount of CSs nowadays has brought further risks for the mother and the baby (25% of the cases) rather than benefits (10-16%) (6). Therefore, with the aim to increase again the number of vaginal deliveries for women who meet the criteria, and provide accu-
rate patient guidance, it is a top priority to gain knowledge of all factors advocating VBAC (6). In support of that statement, guidelines from international sources (7), have stated that women who have previously experienced cesarean sections and are now in the middle of a low risk pregnancy, should be informed by their care providers regarding the exact benefits and risks of both VBAC and elective repeat cesarean section (ERCS). Usually, women rely their decision of having VBAC on the ability to have a speedy recovery (8-11), the wish to experience a natural birth (8-13) and the desire to initiate the processes of bonding and breastfeeding faster (9, 10). On the other hand, women who prefer ERCS seem to take into consideration factors such as the avoidance of pain and possible vaginal damage (14) and the ease of a scheduled birth (11). In 2017, Bonzon et al (6) tried to trace the factors that frequently lead to the choice of VBAC, by developing a multivariable logistic regression model. Researchers found that most important factors influencing a woman’s choice towards VBAC include care provider recommendations and a wish for VBAC, while in cases when women were in contact with midwives during gestation, they had almost twice the odds of preferring VBACs than the ones that didn’t. Signore et al (2012) (15) categorized factors into groups of two, depending on their relation to either increased or decreased probability of VBAC success. Factors such as previous VD and/or VBAC, non-recurring indications for prior CS and greater cervical dilation at admission or rupture of membranes were again associated with increased success rates. To the contrary, hispanic ethnicity, African-American race, increased maternal age, single marital status, less than twelve years of education, obesity, maternal disease (ie, hypertension, diabetes), delivery at rural or private hospital, post-term labor, labor induction or augmentation and fetal macrosomia, related to decreased VBAC success rates. Fineberg and Tilton (2012) (16) indicated that ERCS presents a greater amount of common risks than VBACs, in spite of what many people may choose to believe. VBAC using water immersion has not received proper attention yet, although water immersion VBACs are thought to be a very promising mode of delivery, as small scale records claim that they have zero adverse effects on both maternal and fetal well-being. McKenna et al (2014) (17) discovered the two main reasons lying behind the choice of the specific mode of delivery were related to preventing events that had previously led to CS and counteracting previous bad childbirth experience. Bonanno et al (2011) (18) discussed the medico legal aspects of VBAC, suggesting that hospitals are hesitant in conducting VBACs nowadays, fearing the probable complications (19) and the legal consequences that may follow. Addressing the matter, a NIH Consensus Conference Statement revealed that the medical and legal relationship acts as a barrier to the availability of TOLACs. Although the factors that influence VBAC’s success rates have been studied (15, 20, 21), the need to further investigate VBAC related matters it is also highlighted, in a way that obstetricians can provide evidence-based counseling, increase women’s trust in the specific mode of delivery and play a role in determining the final choice of the mother (22). Although many VBAC prediction models have been developed over the years, none has shown outstanding performance. Thus, the need to explore new approaches and modeling methods other than the usual statistical methods in assessing VBAC and CS success rates is underlined in recent studies. It is claimed that popular multivariable logistic regression techniques have limitations (23), since they fail to examine multiple interactions among independent factors, and they fall short in identifying conditions that prevail in sub-groups. Furthermore, they largely ignore intuition despite its contribution to decision making is well recognized (23). Therefore, many researchers have recently stressed the need to investigate new methods such as machine learning methods, neural networks, and fuzzy logic (23-27).

2. OBJECTIVE

This research aims to construct two fuzzy models, the Fuzzy vaginal birth after cesarean (VBAC) model and the fuzzy CS model in order to assess the medical profile of pregnant women and to suggest the most suitable type of delivery.

3. MATERIAL AND METHODS

In order to adequately address the multi-dimensional nature of the judging the most appropriate type of delivery this research specified a comprehensive set of factors. Following a careful review of the relevant literature and as a series of interviews with a group of 29 experienced obstetricians two sets of 27 and 12 factors were identified that support the adoption of VBAC and CS, respectively. The factors pertain to seven groups related to the: 1/ Mother, 2/ Previous Pregnancies, 3/ Fetus, 4/ Delivery Induction or Augmentation, 5/ Obstetricians and Midwives views.

In order to construct the two fuzzy models, both sets of factors that advocate VBAC and CS, respectively were organized in two separate hierarchies one for each set of factors. Two questionnaires were constructed one for each hierarchy, and they were used to collect data from a group of 29 highly experienced obstetricians each one exhibiting more than 15 years of experience. The expert obstetricians were asked to compare the factors pairwise and to express their belief regarding the relative importance of the factors separately in each of the fuzzy VBAC and the fuzzy CS models.

The FAHP method was utilized to construct the two fuzzy models, and to evaluate the overall degree of appropriateness of adopting VBAC or CS. The proposed models were tested for their ability to produce results that are reasonable, by analyzing pregnant women cases and comparing the models outcome with the expert obstetrician’s suggestions.

Fuzzy Analytic Hierarchy Process

The FAHP introduced by Saaty (1980) (28), utilizes fuzzy numbers in order to model the inherited subjectivity in experts’ judgments. The FAHP calculates the relative importance of the criteria, through a series pairwise comparisons performed by domain experts (29). The FAHP evaluates the consistency of experts’ judg-
ments by using of the Consistency Ratio (CR) (28). The current research calculates the CR using the modal values of fuzzy sets (30). If CR<0.1 then responses are consistent. If not consistent then experts may be asked to review their judgments. The extent analysis method introduced by Chang (29) is a popular method to solving Multi Criteria Decision Making problems with FAHP (31-33). Fuzzy logic has been extensively used in many domains but not in obstetrics. To our best knowledge there has been no other previous study utilizing fuzzy in assessing types of delivery and estimating the degree suitability of VBAC or CS. Although, fuzzy logic application in obstetrics are very limited, its potential for developing fuzzy logic systems generally in medical problems has been highlighted by many recent research efforts (34-35).

4. RESULTS

Experts’ answers were given by using the linguistic scale and the corresponding Triangular Fuzzy Numbers (TFNs): \(\text{Equally important (1,1,1)} / (1,1,1), \text{Weakly important (2/3,1,3/2)/(2,3,1,3/2)}, \text{Fairly more important (3/2,2,5/2)/(2,5,1,2,3/2)}, \text{Strongly more important (5/2,3,7/2)/(2,7/1,3,2,5)}, \text{Extremely more important (7/2,4,9/2)/(2,9,1,4,2/7)}\). Expert answers were aggregated by calculating the geometric mean of their responses. The linguistic scales and their corresponding TFNs were adopted from (32, 36). The top 5 factors of the fuzzy VBAC model that suggest adopting VBAC and the top 5 factors of the fuzzy CS model that suggest CS and their associated importance weights are shown in Figure 1.

The experts’ answers were consistent for both the fuzzy VBAC and CS models (CR=0.010339<0.1, CR=0.009873<0.1 respectively). Table 1 shows the seven-group factors in its sections and their corresponding importance for the fuzzy VBAC and fuzzy CS models. Regarding mother related factors, section 1 of Table 1, indicates that pre-existing disease that requires C-section and mother’s BMI>40 are the two more important factors, which suggest CS adoption, while mothers’ request is the most significant factors to suggest VBAC. With respect to previous pregnancies factors, section 2 of Table 1, results show that previous bowel/bladder injury is the most important reason to adopt VBAC. As regards the adoption of CS, prior uterine rupture or dehiscence constitutes a top reason to examine. Section 3 of Table 1 indicates that all four fetal related factors advocate the adoption of CS, with the most important one to be the fetal distress. Regarding the current pregnancy, in case the obstetrician judges the pregnancy is of high risk, decision leans towards adopting CS. Similarly, twin gestation is another important factor to consider that supports CS. Finally, health care providers’ recommendations are important to consider when suggesting VBAC as shown in section 7 of Table 1.

5. DISCUSSION

Model Validation

The proposed fuzzy VBAC and fuzzy CS models are validated by analyzing pregnant women data. The models’ results are compared and contrasted with obstetricians’ suggestions regarding the recommended type of delivery of the tested women cases. Statistical analysis was performed to examine if there exists a statistical difference between the models’ and the obstetricians’ recommendations. The validation process consists of three steps:

1 step: Expert Obstetricians’ Diagnosis

The group of 29 experienced obstetricians participated in this study, was asked to recommend VBAC or CS for a number of pregnant women test cases. For each pregnant woman data is collected as required by the factors considered in the VBAC and CS fuzzy models. The linguistic scale used by the experts to express their judgments was adopted from Dawood, et al (2021) (37). The linguistic scale are: Very Low Importance (VL)/(0, 0, 0.2), Low Importance (L)/(0, 0.2, 0.4), Medium Importance (M)/(0.2, 0.4, 0.6), High Importance (H)/(0.4, 0.6, 0.8), Very High Importance (VH)/(0.6, 0.8, 1). Expert judgments (), are aggregated since are not necessarily always the same. Expert consensus, in FAHP, is usually calculated using the geometric mean, which is assumed to capture expert consensus more accurately (38). This paper uses TFNs with geometric means to represent expert consensus. Thus, the aggregated TFN of the obstetricians’ responses is denoted simply as a triple , where:

\[
a = \min(e_i), \\
b = \max(e_i), \\
m = \sqrt[2]{\prod_{i=1}^{n} e_i},
\]

represents the lowest of all experts’ judgment, and represents the response of the its obstetrician,

is the geometric means of (), indicating the aggregation of all experts’ judgments, and represents the highest of all experts’ judgment. The aggregated diagnosis is subsequently fuzzified using the following (4):

\[
f_{a}(x) = \begin{cases} 
\frac{x-a}{m-a} & , \ a \leq x \leq m, \ m \neq a \\
\frac{x-b}{m-b} & , \ m \leq x \leq b, \ m \neq b \\
0 & , \ otherwise 
\end{cases}
\]

where a, m, b are real numbers. Thus, obstetricians’ responses are expressed in terms of the specified linguistic terms and TFNs.
2nd step: Model-based diagnosis and fuzzification

The values produced by the fuzzy VBAC (VBAC ∈ [0,1]) and fuzzy CS models (CS ∈ [0,1]) indicate the suitability degree of adopting VBAC and CS, respectively. The numerical outputs of each model are subsequently fuzzified, i.e., they are associated with one of the specified linguistic terms.

3rd step: Investigate differences between the obstetricians and model-based diagnosis.

The model-based recommendations are then compared with the obstetricians’ judgments. This step compares the diagnoses proposed by the experts and the model. The (t-test) was applied to investigate if there exists a statistically significant difference between the obstetricians’ views and the models results for either the VBAC or the CS suitability for each case tested.

Using the fuzzy model for diagnosis

Assume the following data set that represents the profile of a pregnant woman according to the requirements of the proposed fuzzy model. The obstetrician judges and assigns a fuzzy linguistic term for each factor of the individual test case. The fuzzy terms are then defuzzified for each model. Additionally, the obstetrician suggests a type of delivery (VBAC or CS) as well as their corresponding degree of suitability, also in linguistic terms. For example in a case the obstetrician suggested VBAC to woman (k), number of VBAC or CS factor, depending on the model, W_i^k is the degree associated following the obstetrician’s judgment regarding woman case (k), VBAC or CS factor (i), FAHP_i, indicates the fuzzy model calculated weight for VBAC or CS factor (i).

After completing the calculations for this test case, the VBAC= 0.36120376 and CS= 0.067. Thus, the models suggest that VBAC is the more appropriate type of delivery. Using formula (4), in linguistic terms, the membership degree for the Low and Medium fuzzy sets follows respectively: \( f(\text{low}) = 0.19 \) and \( f(\text{medium}) = 0.81 \). Therefore, the model’s suggestion is Medium Suitability of VBAC. The t-test results (p<0.05) indicate the high level of predictive accuracy of the model, after examining the models recommendation accuracy by analyzing data from 57 carefully selected cases of pregnant women. Therefore, the models can be used in conjunction as a valid approach for recommending the most appropriate type of delivery, by calculating the suitability degree for VBAC and CS, respectively.

5. CONCLUSION

Decision making with reference to mode of delivery must give attention to the patient’s personal preferences, obstetric history, data on the risks and benefits of a trial of labor after cesarean (TOLAC) versus planned repeat cesarean delivery (PRCD), and availability of TOLAC in the selected birth setting. Planned TOLAC may result in labor with vaginal birth (VBAC) or unplanned intrapartum cesarean delivery. This study is to our knowledge the first study to utilize fuzzy logic and multi-criteria analysis in assessing the medical profile of women and to suggest the most suitable type of delivery namely VBAC or CS. The proposed approach incorporates the experience as well as the knowledge and intuition of highly experienced obstetricians into two fuzzy logic models. Each of the models (i.e., the fuzzy VBAC and the fuzzy CS model) calculate the suitability degree of each type of delivery given a pregnant woman medical profile. The fuzzy VBAC considers 9 variables while the fuzzy CS model analyses 27 factors related to a pregnant woman. The fuzzy logic approach presented in this research adopts a comprehensive perspective in assessing the most suitable type of delivery for it allows obstetricians and midwives to encapsulate experts’ intuition which is particularly important in delivering personalized advice to pregnant women. The proposed model has been tested by comparing their recommendations against experts’ judgments. The statistical testing indicated the quality of the model to produce results accepted by the experts. Future research should aim to further investigate the validity and the predictive value of the model, as well as to integrate the proposed approach with machine learning algorithms.

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