Delivery Type Prediction Systems Using Machine Learning: A Survey

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Abstract*— The review of delivery type prediction is based on machine learning models. We develop a machine learning model that analyzes the partograph data to predict potential complications and or the need for medical interventions. There are many ideas and observations regarding the use of partographbut there is no clear understanding of the implementation of this partograph. The model uses a set of parameters by examining the mother's status and fetal condition and the ongoing labor progression. The objective of the survey is to identify the best algorithms used for predicting the delivery type i.e, normal delivery or cesarean delivery using machine learning.

***Keywords*— Partograph, Monitoring, Labor, Cervical dilation, Contraction, Amniotic fluid**

I. INTRODUCTION

Partograph serves as a tool for tracking the progress of labor and monitoring the conditions of both the mother and the fetus. The data is recorded in graphical form which is used in decision-making in case of abnormalities during labor. In order to achieve the output, we develop models based on machine learning algorithms. For predicting the output, we make use of the partograph. According to government of India, it is estimated that there were nearly 1.3 million Indian women died during labor and this may be due to several reasons. This was recorded for over last two decades. The use of partograph helps in understanding the condition of both mother and fetus and identifying the complications at early stage to ease the labor. The partograph also helps the health workers for better understanding of labor.

If the delivery type can be estimated, it helps in reducing unnecessary medical complications as it is good for mother and the fetus. This also reduces the risks during delivery and can prevent or decrease the death rates, keeping both mother and infant in safe hands. The World Health Organization (WHO) has given the nod for active labor, suggesting it as a prime time to employ unconventional approaches. The primary objective of the project is to evaluate the health conditions during labor and predicting the delivery type for safe delivery, using machine learning. To better understand the use and need of partograph, we ought to understand the background of partograph or how it was developed over the years. In the year 1952, on June 11th the Friedman curve was said to be introduced on the basis for presenting the labor progression in graphical form. But, the actual curve was introduced in the year 1954 based on some observations.

The idea of partograph was started when Dr. Emanuel Friedman could not attend his first child's birth due to work. He couldn't be with his wife, so he contacted the hospital and recorded the cervical dilation from time to time in graphical form. The data was recorded for the entirenight, overseeing the well-being of all women in the ward. Although the frequency of contractions was not that informative, he concluded from cervical dilations that they followed a S-shaped curve, also known as sigmoid curve.As the first recordings was done on the day the child was born, it is known that the curve was introduced in 1952. Based on his observations, he thought of dividing the labor into latent and active phases for better examination and understanding. In 1954, Friedman presented an analysis in graphical way which includes the case studies of all the 100 women he studied. He recorded the frequency of contractions and cervical dilation per centimeter. The curve is called "The Friedman curve" or "cervicograph". Again, in the year 1955, he studied overall 500 women based on their labor progression and later published his second paper.

According to Friedman observations, the labor was divided into four phases based on the cervical dilation. The phases are as below:

1.Latent phase - Slow dilation (up to 2.5cm)
2.Acceleration phase - Rapid increase of dilation and change in slope
3.Maximum slope - Cervix dilates in linear fashion
4.Deceleration phase - Cervix is fully dilated and shows a change in slope

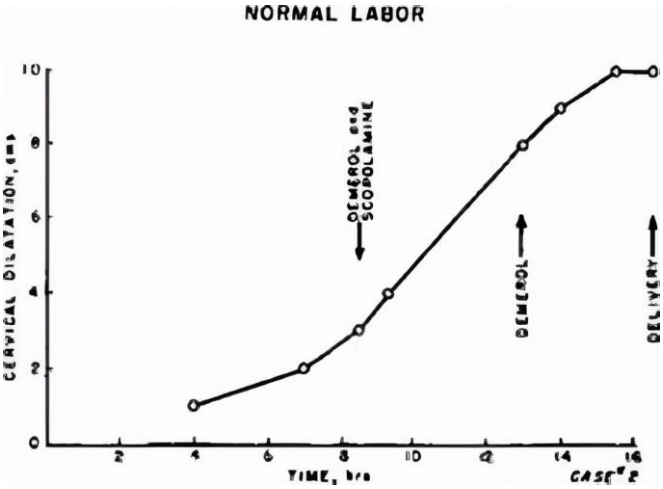

Fig1: Normal labor curve (Friedman curve,1954)

Dr. Philpott developed a partograph based on the Friedman curve. It includes two different lines. They are: The alert line was referred as an indication or warning and ifit crosses the action line, it shows that there is need for medical intervention. Later, this was introduced to England. John Studd, the British gynecologist, made some changes and modified the tool. The nomogram replaces the alert and action lines utilizing cervical dilation post admission as a reference.

Finally, in the year 1994, the World Health Organization approved partograph. WHO recommended the use of partograph in all the labor wards for safe delivery purpose. It is recommended based on the study of more than 35,000 women. The use of partograph resulted in the decrease of mortality rates and also reduce the risk of prolonged labor. The WHO modified version of partograph, the labor scale is used for studying the conditions in labor. Overall, this is how the partograph has evolved, developed and used over the years.

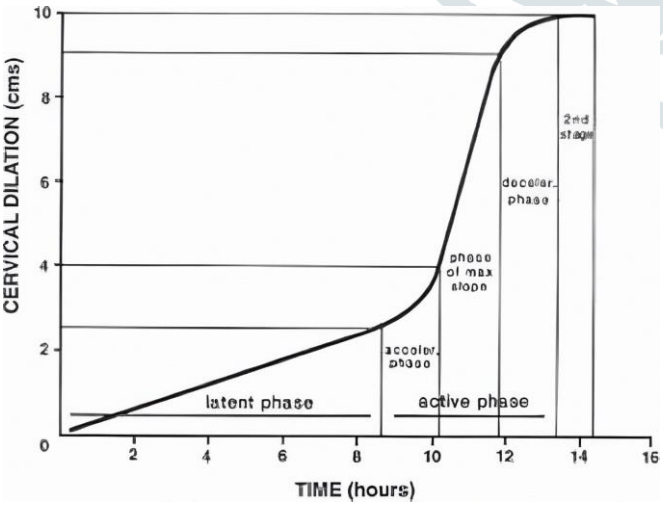

Fig2: Phases of labor representation

II. Literature Overview

According to our understanding and analysis on different papers, we came to some conclusions and identified some observations.

Tina Lavender *et al* [1] scrutinized the partograph's significance in labor. It covers the history of the partograph, its limitations, and the evidence for its effectiveness in improving clinical outcomes. They also discussed the different variations of the partograph tool that have been developed and the contextual factors that can impact its success. Additionally, the paper provides practice points and a research agenda to guide the use and further development of labor monitoring tools. They referred several studies and reviews to support their arguments and conclusions.

GJ Hofmeyr *et al* [2] describes a new approach to labor monitoring called the next-generation partograph. The tool is designed to provide individualized care for women in labor, with a focus on respectful maternity care. Key features of the next-generation partograph include a new approach to labor duration, which takes into account individual differences in labor progression, as well as triggers for clinical interventions based on maternal and fetal well-being. The tool also emphasizes the importance of communication and shared decision-making betweenhealthcare providers and women in labor. The authors argue that the implementation of the next-generation partograph could result in enhancing the health outcomes, as well as heightened satisfaction with care experienced by laboring women.

Abo Bakr A. Khali *et al* [3] explored the reassessment of a digital partograph in labor management. The research sought to improve the quality of labor and prevent complications by monitoring labor progress accurately. The results showed promising outcomes, with a mean delivery duration of 3.5 hours in primigravida and 3.3 hours in multipara after Alert ETD. The research included 800 women in labor, and the average age was 25.6±5 years, with an average parity of 2±1.3. The study concluded that the paperless partograph was an effective tool for managinglabor and improving neonatal outcomes.

Xiaoqing He *et al* [4] analyzed 62 studies to identify new insights into labor patterns. The review challenges traditional labor curves and definitions of abnormal labor, and has important implications for international intrapartum care practices. The authors delve into the revitalization of research on labor progression in the last two decades. They highlight the increasing agreement that establishing abnormal labor may not be linked to an idealized or typical labor curve.

Kidest Getu Melese *et al* [5] focused and studied on the utilization of partograph during labor in Southern Ethiopia. This research aimed to evaluate the understanding, perspective and utilizing the partograph in obstetric care

within the region. The research found that, although the majority of the participants had good knowledge of partograph, their attitude towards its utilization was not always positive. The study also showed that utilization of partograph was influenced by various factors, including the availability of necessary equipment and supplies, workload, and training. The authors stress the significance of advocating for partograph utilization in healthcare facilities to enhance maternal and fetal outcomes in labor.

Ashour E.S. *et al* [6] conducted a study in Egypt toexplore the impact of implementing intrapartum digital versus paper Partographs on maternity nurses' performance and birth outcomes. The study found that the use of digital partographs during labor led to improved performance by maternity nurses, including better documentation of labor progress and timely interventions. Additionally, the use of digital partographs was linked to improved maternal and neonatal outcomes, leading to lower rates of cesarean section and admission to the neonatal intensive care unit. The study suggests that the adoption of digital Partographsin labor wards could improve maternal and newborn health outcomes in other settings.

Carol Bedwell *et al* [7] explored the partograph, a tool utilized for monitoring labor progression and well-being. The review comprised of five steps: defining the review scope, searching for evidence, evaluating primary studies and extracting data, synthesizing findings and drawing conclusions, and finally, disseminating, implementing, and evaluating. The review included 95 papers spanning diverse methodologies, policy documents, audits, grey literature, and opinion pieces. The review indicated that while the partograph can effectively monitor labor progress and well-being, but its effectiveness is influenced by various contextual factors, including health worker acceptability and competence, as well as potential limitations in its clinical application.

Yeliz Doğan Merih's *et al* innovation, the Electronic Touch and Partograph Device [8], revolutionizes obstetric labor follow-up. This electronic device combines vaginal touch and partograph digitally, allowing for real-time monitoring and simultaneous record-keeping for up to 50 patients. Developed between 2016 and 2020, rigorous R&D processes were undertaken, with ethical approvals secured for the study. The device ensures safety for both pregnant women and healthcare professionals, enhancing the well- being of both patient and employees while optimizing labor follow-up. Its potential benefits when introduced to the market promise significant advancements in obstetric.

Singh *et al* [9] presents a quality improvement initiative to increase the use of the modified WHO partograph in labor rooms. The aim was to enhance both maternal and neonatal outcomes by monitoring labor regularly and timely. Theteam identified the root cause of low partograph use and implemented various strategies to increase it, such as triage room allocation, training of residents, involving interns and nurses, formulating departmental written policies and designating authority for oversight. The success of the interventions was measured by the percentage of partographs used, which increased from 25% to 95%. The study found that constant supervision, training, and making partograph available were key to increasing its use. The team faced challenges such as printer issues and misplaced partographs, but they were able to find solutions and improve the quality of care for women in labor.

Shivani Sharma *et al* [10] conducted a study onenhancing safe motherhood through the use of a novel partograph. The study highlights addressing the imperative of eradicating avoidable factors leading to maternal mortality and how the use of a partograph can help detect abnormal labor and provide timely intervention to mothers. The research involved developing and validating a valid and reliable partograph, which was evaluated for its effectiveness and utility in improving labor outcomes. The study concludes that the use of a partograph can dramatically enhance outcomes for both mothers and newborns and recommends its widespread implementation in labor monitoring. The results of this study is useful for healthcare professionals and policymakers in improving maternal and child health outcomes.

Nirmalya manna *et al* conducted a study on the effect of partograph use on outcomes for women in spontaneous labor at term. The study [11] was published in the Cochrane Database of Systematic Reviews in 2013 and found that use of partograph during labor led to reduction in the number of caesarean sections and instrumental deliveries, as well as a decrease in the length of labor. The authors concluded that the use of a partograph is beneficial for both mother and baby and should be used routinely during labor. This study is one of the many pieces of evidence that support the use of a partograph during labor and highlights its importance in improving outcomes for women and their babies.

Jennifer Schweers *et al* discusses the development and evaluation of m-Labor [12], a mobile application designedto improve childbirth outcomes. The applicationincorporates the implementation of digital partographs and workflows to facilitate the management of labor wards. The design of mLabour involved tradeoffs between competing design requirements, such as balancing the user's need for familiarity with the need for innovation. The evaluation of mLabour involved preliminary testing with nursing staff anda study of the application's use at a hospital in New Delhi. It discusses the challenges of inconsistent partograph usageand under-resourced facilities in India. Overall, it provides insights into creating and assessing a mobile application's design aimed at improving maternal and child health outcomes.

Dr. Asma Begum *et al* conducted a study [13] at Dhaka Medical College Hospital from July to December 2009,

involving 50 patients in second stage of labor. The analysis identified key factors affecting delivery outcomes, including the duration of labor, contraction strength, and fetalposition. Notably, 59% of patients required laboraugmentation, and 48.1% underwent artificial rupture of membranes. Among the deliveries, 70% were normal vaginal deliveries, 10% were assisted vaginal deliveries, and 20% were lower uterine cesarean sections. Fetal distress, malrotation, and cephalopelvic disproportion accounted for LUCS cases (40%, 20%, and 40%, respectively). This research underscores the importance of assessing labor conditions to enhance maternal and neonatal well-being.

Berhan Tsegaye Negash and Yitateku Alelgn conducted in Hawassa city public health facilities, Sidama region, Ethiopia, the study focused on the utilization of partographs by skilled birth attendants [14]. The findings highlighted that factors such as profession type, on-the-job training, and knowledge of proper partograph use had a significant influence on its adoption. The study emphasized the benefits of using partographs, including early detection of labor progress deviations, reducing morbidity and mortality, and offering a simple standard for monitoring labor. In conclusion, the research stressed that proper partograph utilization is crucial for preventing maternal and fetal health complications, recommending regular training for healthcare providers to enhance maternal and fetal well-being.

Dr. E. Philpott *et al* investigates the role of the partograph as a labor management tool and midwifery record in South Africa [15]. The study aims to understand midwives' perceptions of its usage and identify factors contributing to its underutilization during labor management. Data was collected through a questionnaire distributed to midwives and analyzed using statistical methods. The paper underscores the advantages of employing the partograph to monitor both fetal and maternalwell-being during labor while shedding light on common reasons for its underuse. Ultimately, the study highlights the significance of accurate partograph recordkeeping for the benefit of healthcare professionals and expectant mothers in labor.

Dr. Dinesh Sharma *et al* conducted a study on "Clinical Evaluation of Course of Labor Using Modified WHO Partograph" [16]. The study aims in assessing the modified WHO partograph in monitoring the course of labor and improving maternal and fetal outcomes. The study was conducted on 400 nulliparous women in labor, and the data was analyzed using SPSS version 20. The results showed that utilizing the modified WHO partograph significantly lowered the occurrence of extended labor, cesarean section, and instrumental delivery. The study concludes that the modified WHO partograph is an effective tool for monitoring labor and improving maternal and fetal outcomes.

Azeb Abraham Hagos *et al* presents a study regarding the use of Partograph by midwives in Addis Ababa, Ethiopia [17]. The study aims to assess the use of partograph and its predictors among midwives working in public health facilities. The study identified that the overall attitude of midwives towards partograph utilization was positive, with 96.2% of respondents having a favorable attitude towards it. However, the study also identified several barriers to the effective use of Partograph, including inadequate training, lack of supplies, and high workload. The study concludes that improving the utilization of Partograph among midwives could contribute to improving maternal and fetal health outcomes in Ethiopia.

Uma Sharma discusses a pictorial presentation of labor and detailing observations on cervical dilatation, effacement, descent of the presenting part, as well as the strength and duration of uterine contractions. Furthermore, fetal and maternal conditions are recorded onto the partograph. The tool [18] is available to a wide range of healthcare workers in maternity care, with both paper and electronic versions. Additionally reported benefits include its practicality during shift changes for seamless care transition and its effectiveness as an educational tool for teaching student midwives about labor progress.

III. Methodologies & Approaches

From the review of all the papers, we have observed that there used several methods and different approaches for understanding and using the partograph. There are various studies and recordings based on the partograph but, they are not implemented to that extent.

We have understood that the better use of the following algorithms or approaches gives appropriate results and also overcome some limitations of the papers. The algorithms that are used to achieve the output are decision tree classifier, KNN, logistic regression. Using these machine learning algorithms we predict the output of our problem.

These algorithms comes under supervised machine learning algorithms. They are explained as below:

A. Supervised Machine Learning Algorithms

Supervised algorithm is a type of machine learning algorithm. It uses a trained data called labelled data and has input data called as labels. Using this data, the model is trained. By providing a test data, the output is predicted.

B. Decision Tree Classifier

The name itself suggests that it is used for decision making purpose. The decision tree has two nodes, decision node and leaf node. The leaf node is output for the decisions. It is basically a yes/no type decision making. If yes, next decision node, else leaf node.

C. K-Nearest Neighbor

The K-nearest neighbor is in-short known as KNN. It stores all the data that is available. Whenever a new data is appeared, it is classified based on the similarities of the available data. Basing on these similarities, the new data is classified and stored.

D. Logistic Regression

The logistic regression predicts the output as a categorical or discrete value. It takes a set of independent variables, using those variables it predicts the dependent variable. The output can be 0 or 1, yes or no etc. It gives the probability as either 0 or 1. For values above threshold, the result is 1 and for values below threshold, the result is 0.

IV. Result Analysis

Table 1: Summary of parameters used

S. No	Methods	Cervical Dilation	Fetal Heart Rate	Maternal Conditions
1	Decision Making	✓	✓	✓
3	Analytical Study	×	×	✓
4	Statistical Methods	✓	×	×
9	Root cause Analysis, Fishbone Analysis	✓	✓	✓
10	Non randomized algorithm	✓	✓	✓
12	Qualitative, Quantitative methods & Decision making	✓	✓	✓
13	Observational analysis	✓	✓	✓
14	Binary, multivariate logistic regression	✓	✓	✓
16	Statistical analysis	✓	✓	✓

Cervical Dilation: The cervix dilation is an important aspect or parameter to find the delivery type for a woman in labor. The cervix dilates from 1cm to almost 8-10cm for vaginal delivery.

Fetal Heart Rate: Fetal Heart Rate denotes the heart rate of the fetus present in the uterus. The heart rate normal condition should be in the range of 120 to 180 beats/min.

Maternal Conditions: The maternal conditions denote the conditions of mother. The conditions or parameters include temperature, pulse, blood pressure, amniotic fluid changes. Each and every parameter have a specific condition.

All these parameters help in predicting the type of delivery. In case of abnormalities, medical intervention can be provided and can proceed to caesarean delivery.

Table 2: Parameter study analysis

No	Mode/Parameters	No. of cases	Percentage
3	1. vaginal delivery 2. vaginal delivery with episitomy 3. Lower segment c s	622 83 95	77.75 10.375 11.875
4	1. Dilated by 4cm 2. Dilated by 5cm 3. Dilated by 6cm		50 74 89
6	1. Primigravida 2. Multigravida	48 52	48 52
10	1. NVD 2. LSCS 3. Instrumental	179 08 13	89.5 6.5 0.5
11	1. pre-term labor 2. post-term	25 4	19.08 3.05
13	1. Cephalic (NVD) 2. Cephalic (LUCS) 3. Rupture (NVD) 4. Rupture (LUCS) 5. Intact (NVD) 6. Intact (LUCS)	31 10 17 6 18 4	88.6 100 48 60 51.4 40
14	1. Cervical dilation 2. Descent 3. Uterine contraction 4. FHR	348 222 340 298	94.1 60 91.9 80.5
15	1. Stated maternal vital signs 2. FHR 3. Cervical dilation	15 4 14	44 41 41
16	1. Arrest of dilation 2. Protracted descent 3. Protracted dilation 4. Arrest of descent	6 8 8 10	18.75 25 25 31.25

The above table represents particular parameters and how they are studied through different and multiple number of cases. The percentage for each parameter is evaluated based on the number of cases. Understanding of each parameter is helpful to analyze the conditions of a labor woman and how regular monitoring can help to acquire accurate result. The analysis helps to understand how a parameter can affect the delivery. This observation helps to predict whether the delivery can be vaginal type or caesarean type or need for any medication in case of abnormalities.

V. Findings & Trends

Analyzing all the papers, we have noticed several studies and observations regarding the partograph. There are different, of which the partograph is used for women in labor. Various algorithms like logistic regression, decision making are used. Studies found that its implementation can be done using machine learning, artificial intelligence. The partograph may be either paperless partograph or electronic partograph or mobile partograph. The decision making is used effectively at the introduction stage of partograph. Many case studies have been recorded by studying various women under different conditions. Thus, predicting the delivery type using this, helps in healthy and safe delivery.

VI. Challenges & Gaps

Although, the use and study of partograph is recommended by WHO, there is an edge between the study and implementation. Observations and studies provide the idea about its use and importance but implementation is a practical method. The use of partograph in labor helps to record the health conditions, so that monitoring can be done effectively and also to identify the abnormalities and providing necessary medications. It also reduces the mortality rates thus, safeguarding both mother and fetus. The main challenge faced here is, the proper implementationof partograph which leads to vast changes in the results.

VII. Future Research Direction

The partograph helps in understanding the health conditions in labor. From the introduction of this concept, it has been evolved with some changes. There are some parameters that analyzes the health conditions or environment necessary for delivery. Many changes have been made over the years.

The analysis of various authors is given above. Basing on the overall analysis we can say that partograph is very useful for health workers, women and baby. There are many case studies, theoretical part about this. Very few authors discussed two or three algorithms that can be used for the implementation of delivery type prediction and some discussed parameters should be taken for this. But, there is no proper implementation of this. The implementation canbe done using any machine learning algorithms. Thus, in the future several improvements can be made and used through studies, research and observations which leads to advancement in medical field.

VIII. Conclusion

Prediction of delivery type of women before few hours of labor helps in safest delivery. Delivery type either vaginal or cesarean effects the health of women and baby. So, choosing the best type is very important. This can be done through partograph. As it is globally accepted and referred by WHO, prior importance should be given to its implementation. From the analysis of papers, we observed that this can be implemented through algorithms related to machine learning and also artificial intelligence. Many researches have been made and going on regarding its implementation. We try to make use of the machine learning algorithms especially, supervised algorithms like decision tree, k-nearest neighbor, logistic regression. This can result to predict the output to maximum accuracy.

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