# Telehealth-based Intrapartum Monitoring: Impact of Clinical and Technical Factors on Remote Decision Making

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***Abstract* - Digital Labour and Delivery Solution (DLDS) is a mHealth-based solution for structured and instant communication during intrapartum care. The primary objectives of this study were – (1) to evaluate feasibility of the DLDS for information exchange among healthcare professionals for remote intrapartum monitoring and decision making; and (2) to study impact of various clinical and technical factors on decision agreements between the doctors. The inclusion criteria for the study were, a live-singleton pregnancy with cervical dilatation $\geq$ 4 cm but < 8 cm at the time of admission, and presenting without any complication necessitating any immediate intervention. The feasibility of the DLDS was evaluated by comparing the decisions taken by a remote doctor using the DLDS to that of decisions taken by a doctor in a labour room. Impact of clinical parameters (mother's age, parity, anemia and presence of intrapartum complications) on decision agreement between the doctors was studied by comparing agreements in different subcategories of these parameters. Similarly, the total number of observation records for a subject were also studied to find their impact on decision making. The overall agreement between the two doctors for 110 cases (220 independent decision points) was 0.764 using unweighted Cohen's kappa and 0.723 using weighted Cohen's kappa statistic. The doctors had comparable agreements in all the sub-categories of the clinical parameters, indicating minimal impact of clinical parameters on decision agreement between the doctors. A significant improvement was observed in the agreement as the total number of assessments available during the course of labour increased. The substantial agreement between the two doctors for intrapartum decision making demonstrates the feasibility of the DLDS for remote intrapartum monitoring and decision making. This also indicates that DLDS was able to convey the appropriate information to the remote doctor in the different sub-categories of the clinical parameters. The study recommends further investigation of DLDS for a general purpose remote intrapartum monitoring.**

***Keywords- feasibility study; inter-observer variability; intrapartum; mHealth; obstetrics; partograph; telemedicine.***

## I. INTRODUCTION

In the last few decades, obstetrics care has evolved significantly from delivery at home, to delivery at a specialty center under the supervision of a trained medical or paramedical team. A short time interval between onset of complications and time to intervene makes intense monitoring and prompt decision making very important during the intrapartum phase. Structured and instant communication can play a very important role to make intrapartum care effective and safe. These are areas where Information and Communications Technology (ICT) can play a major role. In recent times, mobile devices (smartphones and tablets) have emerged as one of the most important enablers of ICT in healthcare. Considering the need gaps in intrapartum communication and the potential of mobile devices for telehealth, we have designed a Digital Labour and Delivery Solution (DLDS). DLDS is a tablet-based solution designed for systematic information gathering and sharing during intrapartum monitoring [1].

Intrapartum monitoring and decision making is a very complex procedure. Availability of structured and instant data is just one aspect of this process. Many other factors such as clinical history and complication of a patient, and technical factors such as how frequently a patient is assessed during course of labour and frequency of vital parameters' recording can also have a significant bearing on decision making. This could be a reason that obstetricians have shown to have a poor agreement during intrapartum decision making [2]. This is especially important during remote monitoring. Therefore, it is equally important to study impact of these parameters on remote intrapartum monitoring.

The primary objectives of this study were to evaluate the feasibility of the DLDS in information exchange among health care professionals for remote intrapartum monitoring and decision making, and to study impact of various clinical and technical factors on decision agreements between the doctors. The feasibility of DLDS in information exchange for remote intrapartum monitoring and decision making is covered in detail elsewhere [1]. This paper mostly focuses on study of impact of various clinical and technical factors on decision agreements between the doctors by comparing agreements in different subcategories of these parameters.

The rest of the paper is organized as follows, Section II summarizes the literature review of the communication tools used during intrapartum phase; Section III covers details of the study protocol and statistical methodology. The study results are summarized in Section IV. Section V provides commentary on overall results and their possible implications for clinical practice. Section VI concludes with the most important findings and future work directions. The acknowledgement section closes the article.

## II. Review of Literature

As the complications during intrapartum phase are responsible for almost 42% of maternal mortality, 32% of still births, and 23% of neonatal deaths [3], prompt monitoring and instant communication is very important during intrapartum phase for an effective decision making. This also highlights need of an effective collaboration between doctors and midwives with well-defined roles and responsibilities. However, contrary to this requirement, it has been observed that intrapartum care suffers from a poor teamwork. A study conducted in the USA has observed that less than 50% of doctors and less than 37% of nurses in labour room rated their teamwork as adequate [4], indicating magnitude of poor teamwork in the intrapartum care.

It is well recognized that a poor teamwork or interprofessional collaboration is one of the important reasons for adverse clinical outcomes and poor delivery of health services and patient care [5][6][7]. Among various issues, which have an adverse impact on teamwork, poor communication patterns have been identified as one of the most important issues. This is evident by a fact that issues in communication have been identified as the root cause in 72% of total cases related to infant deaths and injuries during delivery [8]. Poor communication is usually a result of a poor transmission or exchange of information. Paper-based methods and telephonic communication are two conventional methods used by intrapartum monitoring team for information exchange.

Intrapartum monitoring team is usually composed of midwives/nurses, junior doctors and senior obstetricians working in a labour room. The role and responsibilities of each of them are usually defined and bounded by a hierarchical system, although overlaps do exist. Midwives are primarily assigned for intrapartum monitoring of vital parameters and for basic interventions, while doctors are responsible for clinical decision making and advanced surgical interventions. Midwives are stationed in the labour room all the time during their shifts, while doctors may or may not be constantly present in the labour room due to various other responsibilities assigned to them. In the latter case, midwives regularly update the doctors to get management guidance.

Two important conventional methods of communication during intrapartum monitoring are paper-based method and telephonic communication, a brief review of these methods is presented as follows.

### *A. Paper-based method*

In a conventional paper-based workflow, all patient related information, history and management details are recorded on paper sheets. This time-honoured method is simple to follow, inexpensive and has wide acceptance among healthcare workers around the globe. Although, easy to use and simple, there are few significant disadvantages with this method – (1) the data recorded by this method is often unstructured and non-standardized, this makes it difficult to standardize the care practices; (2) it is not possible to share the recorded information with multiple people simultaneously; (3) this method has been shown to be prone to manual errors, which could be a cause of legal litigations [9]; and (4) over a period of time, storage and retrieval of paper records become quite challenging, which makes it very difficult to use recorded information for any analytics or predictions. The most significant disadvantage from intrapartum monitoring perspective, is the inability to remotely share the critical patient information in real time for collaborative decision making. To make the paper-based method more structured and effective various different approaches have been tried in the past; one important initiative in this regard is the use of partograph for intrapartum monitoring.

The partograph (a.k.a. partogram) is a simple, inexpensive tool, which provides health professionals a pictorial overview of the labour for early identification and diagnosis of the pathological labour. It was first proposed by Emanuel Friedman in 1954, as a cervicograph [10]. Subsequent large multi-centric prospective studies conducted by the World Health Organization (WHO) concluded that partograph was able to clearly differentiate between normal and abnormal progress in labour; the WHO recommended its universal application in all the labour rooms [11]. Following this, a number of studies were conducted across the globe to determine the effect of partograph use on perinatal morbidity and mortality; however, there is still no consensus in the literature on the effectiveness of the partograph [12].

Despite its proven effectiveness in labour monitoring, partograph has not been utilized optimally in many settings across the world [12][13]. It has been observed, that the rate of partograph utilization during intrapartum monitoring varies significantly in different setups, being as high as 97.8% in Niger study to as low as just 1.4% in a study done in Bangladesh [14]. The suboptimal utilization of partograph does not stop here, it has been observed that in most of the cases where partograph is used, the clinical parameters are either not recorded or recorded less frequently than prescribed. It is well-documented that, when information on the partograph is incomplete, misinterpretation is more likely and it may lead to delayed diagnosis, inappropriate or no action, and consequent development of serious complications [15].

Despite its effectiveness, sub-optimal utilization and poor recording of partograph parameters during labour is a matter of great concern for quality intrapartum care throughout the world. To address this issue it is important to understand the barriers for partograph use. Based on published literature, barriers to partograph use can be grouped in three broad categories – (1) implementation related barriers; (2) caregivers related barriers; and (3) clinical workflow-related barriers. Out of these barriers, the caregiver-related issues, mainly – (1) insufficient knowledge on how to use partograph [16][17]; (2) work overload due to shortage of staff [17]; and (3) time consuming nature of partograph plotting were found to be the most important barrier for effective partograph use [18].

To reduce barriers in partograph use and increase its utilization different approaches have been tried across the globe such as PartoPen, mlabour, DAKSH and E-Partograph. These digital initiatives have rejuvenated interest in partograph and have shown a good user acceptance in feasibility studies [19][20].

### *B. Telephonic communication*

Telephonic conversations among healthcare workers are now primary mode of remote consultation and monitoring in intrapartum care. This method is very simple, universally available and offers advantages of real time communication in a cost effective manner. Availability of mobile phones has further enhanced the reach of this method. However, there are few significant disadvantages with this method – (1) effectiveness of communication is limited by education and experience of involved parties; (2) limited access to information, leading to misunderstanding or underestimation of complications [21][22][23]; (3) it is not possible to record information for analysis, or audit or for medico-legal purpose. Moreover, telephonic triaging is considered as the most complex and vulnerable part of the out-of-hospital care process and has also been shown to be associated with patient dissatisfaction [21][24].

To make telephonic conversions more structured and effective various approaches have been tried. One important initiative in this regard is use of **S**ituation–**B**ackground–**A**ssessment–**R**ecommendation (SBAR) technique. SBAR allows the medical team to communicate with each other in a standard way by using a structured method for the transfer of vital information. SBAR technique was first used in military communication, followed by aviation industry for effective communication. This has been later adopted by many health care settings as a communication tool.

SBAR has been shown to be an excellent tool for information sharing and has found application in many sub specialties of medical care. It has been observed in a number of studies that SBAR technique has not only improved communication between healthcare professionals but also has improved the overall quality of care [25][26]. However, a few studies have also reported no or little improvement in overall communication or quality of care [22].

SBAR is shown to be an effective communication tool, but it is not free of disadvantages. It has been observed that – (1) SBAR concept is difficult to learn and practice, therefore it requires extensive education and training along with frequent follow-ups for effective implementation [27]; (2) SBAR approach requires changes in nursing practice [27]; (3) it a is time consuming technique [26].

Despite its limitations, SBAR is a very effective tool for structured communication. To enhance it further there are now attempts to design it in the electronic form. The initial studies have indicated encouraging results in this regard [28].

### *C. mHealth applications in the intrapartum space*

The use of ICT in healthcare has grown exponentially in the last two decades; however, it still lacks way behind in comparison with other sectors like finance, retail, transportation etc. This is usually because of high cost, limited evidences of benefit, non-availability or complexity associated with the new technologies, and lack of end-user centric solutions [29]. Fortunately, mHealth has overcome many of these classical barriers with their ubiquitous presence and high acceptance among end users, even in the remote parts of the world [30]. Availability of cheap and portable computing platform in the form of mobile devices has further accelerated the reach of ICT in healthcare. While mHealth solutions have overcome several barriers of conventional communication tools, other barriers like intermittent power and connectivity, low literacy levels, low levels of technical training, and maintenance and scalability costs are yet to be fully solved.

In the intrapartum space, applications like PartoPen [19], and DAKSH [20] are introduced to make communication structured and more effective. These application have mostly focused on digitization of labour records, partograph and usability aspects. However, none of them have systematically studied their applicability for remote intrapartum monitoring and decision making. Moreover, they have also not studied impact for various clinical and technical factors on decision agreement during remote intrapartum care.

### *D. A summary of literature review and indentification of communication needs for the intrpartum care*

To improve communication during intrapartum care, many tools and techniques such as partograph, SBAR, and digital partograph have been introduced. These are shown to be effective but underutilized due to time constrains and stiff learning curves. The literature indicates that the existing methods of communication have limitations when it comes to clear and real-time information exchange during intrapartum and have been shown to be either inadequate or cumbersome for this purpose [9][21]. Moreover, none of these techniques provide an integrated solution for intrapartum monitoring and decisions, making them of limited use for a hospital setup.

An emergence of affordable smartphones and increase cellular connectivity and data transfer facility with 3G, 4G and upcoming 5G networks are likely to provide a significant boost to the use of the mobile platform for providing healthcare services. On other hand, lack of regulations or stringent regulations and data security issues are likely to be major hurdles for a wide spread use of this technology platform in healthcare. Going forward, one very important driver for this platform will be its high penetration in the developing countries, which have a high burden of diseases, limited human resources and funds to provide adequate healthcare. These countries are likely to be the primary consumers of mHealth solutions.

A digital solution, which incorporates real time data sharing capacities with standardized communication (partograph and SBAR) and decision protocols along with seamless connectivity has potential to address information sharing need gaps and is likely to be a way for future of intrapartum communication. Taking positive trends from digital health journey so far, many mHealth models for information sharing and data processing are already in various stages of development. DLDS is one such mHealth solution for intrapartum care. The DLDS is designed to serve as an integrated solution for remote intrapartum monitoring and decision making.

The primary objectives of this study were - (1) to evaluate the feasibility of the DLDS in information exchange among health care professionals for remote intrapartum monitoring and decision making; and (2) to study impact of various clinical and technical factors on decision agreements between the doctors. We had a primary hypothesis that a remote doctor can be equally adept at decision making if he/she is provided with all the necessary information. The effectiveness of the DLDS was evaluated by comparing the decisions taken by a remote doctor (outside of a labour room) using intrapartum information provided by the DLDS to that of decisions taken by a doctor in a labour room (in-charge doctor). Impact of clinical and technical factors was studied by comparing decision agreements in different subcategories of these parameters.

## III. Material and Methods

This section provides details about the study protocol and statistical methodology.

### A. Study design

This observational study was conducted in a medical college hospital in Mysuru (Mysore), India in 2016. Inclusion criteria for the study were a live-singleton pregnancy with cervical dilatation $\geq$ 4 cm but < 8 cm at the time of admission to a labour room. All the cases with planned caesarean section or cases with complication(s) or indication(s), which required immediate intervention or where a trial of labour was contraindicated were excluded. The study was conducted in accordance with local regulations after approval of an institutional review board. Subjects were enrolled only after obtaining informed consent in writing.

### B. Study protocol

All the enrolled subjects were managed as per the established clinical workflows and protocols of the hospital. The subjects were regularly assessed by an in-charge doctor (doctor involved in an active management of a subject). After each assessment, the in-charge doctor took one management decision from four possible options - (1) “Wait and watch”, i.e., to continue the expectant management without any active intervention; (2) “Accelerate the labour”, i.e., accelerate the labour process either by means of artificial rupture of membranes or by medication; (3) go for “Assisted vaginal delivery”, i.e., use of forceps or vacuum extraction method for delivery; and (4) go for “Caesarean section”.

All the subjects and newborns were monitored up to 24 hours after delivery for any adverse outcomes. Outcomes monitored included obstructed labour, uterine rupture, post-partum haemorrhage, stillbirth, early neonatal mortality, Apgar score at five minutes, and newborn’s admission to a Neonatal Intensive Care Unit (NICU).

For each subject, complete clinical history, examination, investigation details and management decision for each assessment were entered in the DLDS. To prevent any influence of the DLDS on clinical workflow and patient management an additional nurse (not actively involved with patient management) was appointed for data entry in the DLDS. The study workflow is illustrated in Fig. 1.

### C. DLDS application

DLDS has been developed as a monitoring and communication solution for labour, delivery and immediate post-partum care. DLDS is a tablet-based solution built on an Android platform and allows secured sharing of information over a Wi-Fi network. Its intuitive design and user interface allows systematic and easy entry of the past and present history, examination and investigation details of the patient with an option to customize entry fields. It also provides an advanced visualization for various clinical trends and partograph. For guidance (e.g., normal ranges of clinical parameters, recommended frequency of intrapartum parameters assessment etc.) and alerts (e.g., alert and action line for partograph) the well-established guidelines and protocols given by the reputed organizations such as the WHO were incorporated in the DLDS. The DLDS can be used as a stand-alone delivery solution or could be integrated with maternal telehealth platforms such as Mobile Obstetrics Monitoring [31]. For the study, two DLDS tablets were used; the one in the labour room was designed to anonymize and securely transmit information to the other tablet over a wireless network connection.

### D. Workflow of the remote doctor

A doctor who was not involved in the management of any of the study subjects was assigned as a ‘remote doctor’. To ensure that there is no discrepancy in decision making due to skill and knowledge differences, doctors with a similar profile as the in-charge doctor was selected as a remote doctor. The remote doctor was asked to use the second DLDS application to review case records (without management decision information) and enter one of the four management decisions in the DLDS. For each subject, the remote doctor reviewed the case records at the two instances, first at the time of admission and the last record before any active intervention or delivery (refer to Fig. 1).

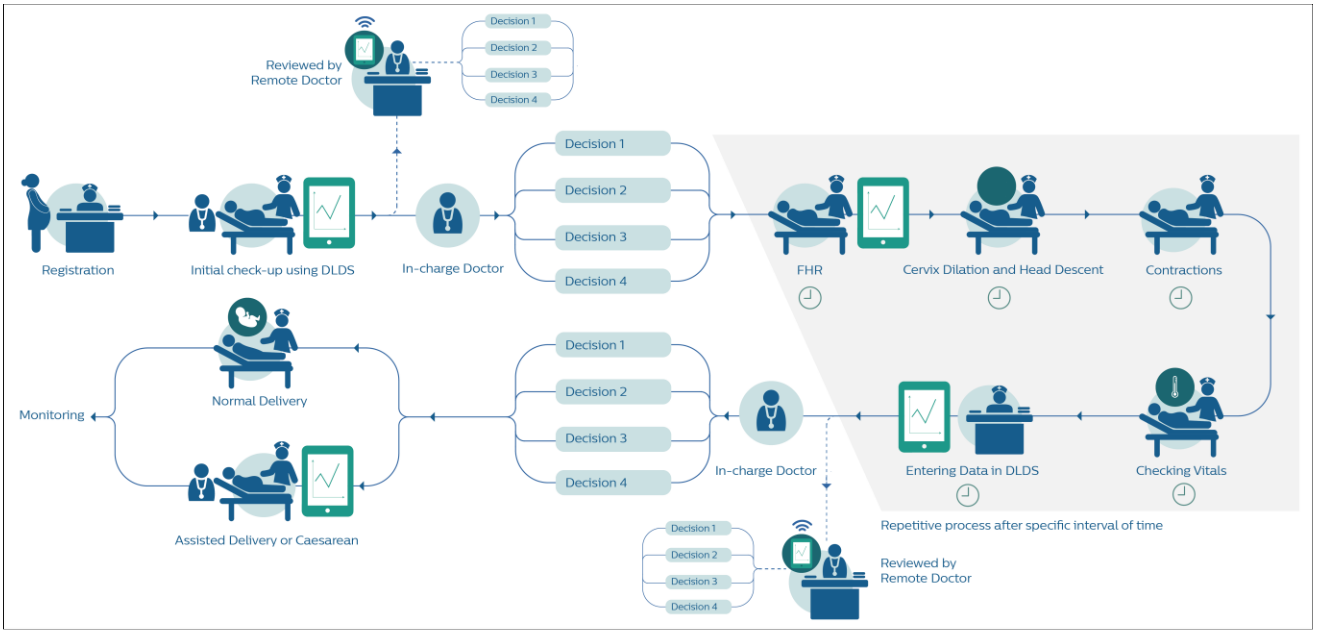


Figure 1. Workflow of the study. Decision 1 to 4 denotes one of the four possible management decisions taken by the in-charge doctor. The remote doctor reviewed the subject records using the Digital Labour and Delivery Solution (DLDS) at two instances and took one of the four possible management decisions.

### *E. Potenial impact of clinical and technical factors on the decision agreements between the doctors*

Decision making during intrapartum phase is a complex procedure. Doctors' consider many clinical parameters during decision making such as the age of the patient, obstetric history, presence of complications and so on. To study the effectiveness of the DLDS in conveying this information, the decision agreements between the in-charge and the remote doctor in various sub-categories of clinical parameters were studied. Other than pre-mentioned adverse outcomes such as obstructed labour, uterine rupture, post-partum haemorrhage, stillbirth, early neonatal mortality, Apgar score, and newborn's admission to a NICU, other clinical parameters such as, mother's age, parity, anemia (Haemoglobin <= 11 gm/dL) and presence of intrapartum complications (leaking/bleeding per vaginam) were also studied to find out their possible impact on decision agreement between the doctors. Impact of clinical factors was studied by comparing decision agreements in different subcategories of these parameters.

Apart from the clinical parameters, technical factors such as a number of times a particular patient is assessed/observed with recording of vital parameters also has bearing on intrapartum decision making. This is especially important for remote decision making. To study the impact of a number of assessments on decision making, the cases were divided in three sub-categories based on the total number of observation records available and decision agreements between the doctors were studied in each of those sub-categories.

### *F. Statistical analysis methodology*

The decisions taken by the doctors for each case were extracted from the two DLDS applications. The agreement between the in-charge doctor and the remote doctor on the four types of management decisions was assessed using the Cohen's kappa statistics. However, as different types of management decisions have different implications in clinical practice, it is important to study not only overall agreement between the two doctors but also an extent of disagreement for individual decisions. This is important as some decisions are closer to each other when compared to other decisions (e.g., a decision to go for "Caesarean section" is much closer to a decision to go for "Assisted vaginal delivery" in comparison to a decision of "Wait and watch").

As Kappa analysis does not account for the difference in decision types, weighted Kappa analysis was used for this purpose. The weights used to grade the differences in decisions are presented in Table I.

TABLE I. WEIGHT MATRIX FOR DECISION GRADING

| **Decision taken by in-charge doctor** | **Decision taken by the remote doctors** | | | |
|---|---|---|---|---|
| | ***Wait and watch*** | ***Accelera-te labour*** | ***Assisted vaginal delivery*** | ***Caesarea-n section*** |
| Wait and watch | 0 | 1 | 2 | 3 |
| Accelerate the labour | 1 | 0 | 1 | 2 |
| Assisted vaginal delivery | 2 | 1 | 0 | 1 |
| Caesarean section | 3 | 2 | 1 | 0 |

The agreement scale proposed by Landis and Koch was used to grade and compare the agreements between the doctors in various sub-categories of clinical and technical parameter [32]. All statistical analyses were done using Microsoft Office Excel-2016 and R (version 3.5.2).

## IV. RESULTS

The study results are summarized in this section.

### A. *Demographic characteristics of the study population*

In total, 110 subjects were enrolled for the study. The mean maternal age was 24.21 ± 2.69 year, with a mean body mass index of 24.48 ± 2.08 kg/m$^2$. The nulliparous women constituted 30.43% of the study population. Gestational age was in the range of 37 to 41.6 weeks (median = 39.55 weeks). The mean birth weight of the neonates was 3037.98 ± 345.25 g, with a range of 2320 g to 4040 g.

### B. *Intrapartum monitoring and labour outcomes*

Throughout labour, all the subjects were monitored using the conventional workflows and protocols of the hospital. None of the cases had any significant antenatal complication. The average duration of labour was 7 hours 3 minutes (± 63 minutes). On an average, each subject was assessed 15.63 (± 0.518) times during labour, which comes out to be one assessment per 28 minutes. During each assessment, vital parameters, examination details and management decision for a subject were entered in the DLDS application.

Five cases were delivered by caesarean section. Two cases were delivered by forceps extraction method. The rest of the cases were delivered vaginally. Four cases had history of leaking/bleeding per vaginam. None of the other cases had any adverse intrapartum or immediate postpartum outcome. All the neonates had Apgar score of eight or more at five minutes and none of them required admission to a NICU.

### C. *Agreement for the management decisions*

The remote doctor was asked to review 220 records (two records per case) using the DLDS. The confusion matrix of the four management decisions taken by both the doctors is summarized in Table II.

TABLE II. DECISION AGREEMENT BETWEEN THE DOCTORS

| **Decision taken by in-charge doctor** | **Decision taken by the remote doctor (using *DLDS)*** | | | | **Total** |
|---|---|---|---|---|---|
| | ***Wait and watch*** | ***Accelera-te labour*** | ***Assisted vaginal delivery*** | ***Caesarea-n section*** | |
| Wait and watch | 103 | 10 | 0 | 0 | 113 |
| Accelerate the labour | 11 | 88 | 0 | 1 | 100 |
| Assisted vaginal delivery | 1 | 0 | 1 | 0 | 2 |
| Caesarean section | 2 | 2 | 0 | 1 | 5 |
| Total | 117 | 100 | 1 | 2 | 220 |

It was observed that for the "Wait and watch" decision the remote doctor was in a perfect agreement with the decisions of the in-charge doctor in 91.15% of total records; for "Accelerate the labour" this agreement was 88%. Agreements for "Assisted vaginal delivery" and "Caesarean section" were 50% and 20%, respectively. Nevertheless, as these two categorizes had very few samples (not even 30 samples, a general requirement for statistical analysis) it is difficult to comment on their statistical significance.

The overall agreement between the two doctors for all the decisions combined was 0.764 using unweighted Cohen's kappa statistics. The weighted Cohen's kappa between the two doctors was 0.723.

### D. *Impact of clincial parameters on the agreement between the doctors*

In this study following clinical parameters, mother's age parity, anemia (Haemoglobin <= 11 gm/dL) and presence of intrapartum complications (leaking/bleeding per vaginam) were studied to find out their possible impact on decision agreement between the doctors. All of these parameters were divided in two sub-categories to compare decision agreements. In study population, none of the subject was over 35 years of age and only a few were above 30 years; therefore, 25 years was used as a threshold to divide subjects in two sub-categories.

The unweighted Cohen's kappa statistics between the in-charge and remote doctor for various sub-categories of clinical parameters are summarized in Table III. It was observed that the in-charge and remote doctor had comparable agreements for all the studied clinical parameters with substantial agreements in all the sub-categories.

TABLE III. IMPACT OF CLINCIAL PARAMETERS ON AGGREMENT BETWEEN THE DOCTORS

| **Clinical parameters** | **Sub category** | **No. of decision points** | **Cohen's kappa** |
|---|---|---|---|
| Age (year) | Age <= 25 | 132 | 0.775 |
| | Age > 25 | 88 | 0.745 |
| Parity | Nulliparous | 80 | 0.747 |
| | Multiparous | 140 | 0.774 |
| Anaemia (Hb <= 11 gm/dL) | Yes | 22 | 0.748 |
| | No | 198 | 0.759 |
| Complications (leaking/bleeding PV) | Yes | 8 | 0.800 |
| | No | 212 | 0.755 |

Hb = Haemoglobin, PV = Per vaginam.

As none of the cases had obstructed labour, uterine rupture, post-partum haemorrhage, stillbirth, early neonatal mortality, low Apgar score, and newborn's admission to a NICU we could not study the possible impact of these complications on decision agreement between the doctors.

### E. Impact of total number of assessments records on the agreements between the doctors

For remote monitoring it is important that a doctor has frequent data from the labour room. To study impact of a number of assessment records on the decision agreements, the cases were divided in three subgroups based on the total number of assessments for each case. The unweighted Cohen's kappa statistics between two doctors for the three sub-categories are summarized in Table IV.

TABLE IV. IMPACT OF TOTAL ASSESSMENTS RECORDS ON THE AGREEMENT BETWEEN THE DOCTORS

| **Parameter** | **Sub category** | **No. of decision points** | **Cohen's kappa** |
|---|---|---|---|
| Number of assessment (records) | <= 10 assessments | 24 | 0.576 |
| | 11 - 20 assessments | 160 | 0.779 |
| | >= 21 assessments | 36 | 0.837 |

As per the Landis and Koch scale, a significant improvement was observed in the agreement between the in-charge and remote doctor as the total number of available assessments records increased. For the group with less than or equal to 10 assessments the doctors had just a moderate agreement among themselves, whereas for the group with more than 20 assessments the agreement was almost perfect.

## V. DISCUSSION

One very crucial part of communication is transmission or exchange of information in a structured way for effective decision making. Unfortunately, the existing modes of intrapartum communications are shown to be insufficient for this purpose [21][22] making them a less reliable medium for information exchange [9][23]. The main objective of this study was to evaluate feasibility of the DLDS application for remote intrapartum monitoring and decision making. This was done by comparing decisions taken by a remote doctor using the DLDS to that of the in-charge doctor. In this regard, a substantial agreement was observed between the two doctors for intrapartum decision making. This demonstrates the feasibility of the DLDS for remote intrapartum monitoring and decision making.

It was observed that the agreement between the doctors for non-operative mode of deliveries was significantly higher than for operative deliveries. This finding is in line with the published literature, where complete agreement for caesarean section decision has been observed to be about 65% [2]. Nevertheless, the lower agreement for operative deliveries (in particular more decisions of "Assisted vaginal deliveries" and "Caesarean section" by the in-charge doctor) needs further investigation. This could be due to the remote doctor missing some crucial information or the doctor in-charge getting negatively influenced by real-life factors such as stress of other emergencies to attend, lack of sleep, or pressure from the healthcare workers or patients. However, as only seven cases were delivered by a non-vaginal route, it is difficult to generalize findings of this study to mode of deliveries other than vaginal.

A number of clinical and technical factors can have a major impact of intrapartum decision making. To study effectiveness of the DLDS in conveying this information, the decision agreement between the doctors in the various sub-categories of the clinical parameters were assessed. It was observed that the in-charge and remote doctor had comparable agreements in all the sub-categories of the clinical parameters, indicating minimal impact of clinical parameters on decision agreement between the doctors. This also indicates that DLDS was able to convey the appropriate information to the remote doctor in all the sub-categories of the clinical parameters. For total number of assessment, a significant improvement was observed in the agreement between the in-charge and remote doctor as the total number of assessments increased. This clearly indicates advantage of having more data points in decision making and also makes a strong case for having frequent and automated monitoring of vital parameters during labour.

Small sample size from a single center and recruitment of just one doctor in the labour room and one for remote assessment are two important limitations of our study. However, as this was a feasibility study we first wanted to test and verify our concept before conducting a large study with multiple doctors. Despite having a small sample size, we compared 220 independent decisions points between the two doctors. Furthermore, as none of the cases in our study had any adverse outcome, it was not possible to assess adequacy and quality of information provided by the DLDS to the remote doctor in such situations. Nevertheless, it was observed that the remote doctor could use the DLDS application for decision making for all the sub-categories of the clinical parameters.

On the study design, the use of an additional nurse for data entry is likely to have contributed to better and more comprehensive data gathering, which may not have been possible in conventional workflows. However, having a complete and accurate data entry is prerequisite for any digital solution and it is bound to have some change in the existing workflow. It also brings the advantage of enhanced patient safety by improving the communication, comprehensiveness, and organization of patient notes [33]. Moreover, it has been also indicated that introduction of digital records are likely to reduce risk and liability for obstetric providers, especially in the intrapartum care [34]. This study has also demonstrated that more data led to a better decision agreement, which further supports advantage of complete and accurate data entry in decision making.

## VI. CONCLUSION

The strength of this study lies in being one of the first studies where the feasibility of a telehealth solution for remote intrapartum monitoring and decision making has been studied systematically. The finding of this study could serve as an important input for further research in this area. In the future, we would like to extend this work on a larger sample size with recruitment of more remote and in-charge doctors. Moreover, we would also like to conduct a dedicated usability study to understand and improve user interactions with the DLDS.

To conclude, our study has demonstrated a substantial agreement in the intrapartum decisions taken by a remote doctor using the DLDS and decisions taken by a doctor in a labour room. The study has also demonstrated that the in-charge and remote doctor had comparable agreements in all the sub-categories of the clinical parameters. This indicates that DLDS was able to covey the appropriate information to the remote doctor in the different sub-categories of the clinical parameters. The study has also clearly indicated advantage of more data points in decision making. This supports the hypothesis that it is possible to remotely monitor intrapartum labour progress and take appropriate decisions if a remote doctor is provided with all necessary information. It further supports use of telehealth solutions such as DLDS for remote intrapartum monitoring. Considering limited resources and shortage of trained healthcare workers in the developing countries, we believe that there is a huge need for intrapartum telehealth solutions in such countries. The study recommends further investigation of DLDS for a general purpose remote intrapartum monitoring.

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