mHealth Solution for Remote Intrapartum Monitoring: A Feasibility Study

Hiwale Sujitkumar, Krishnan Navaneetha, Addepalli Jeevan Ram, and Ulman Shrutin
Philips Research India,
Philips Innovation Campus, Manyata Tech-Park,
Bengaluru, India-560045
e-mail: sujit.hiwale@philips.com

***Abstract*—The primary objective of this study was to evaluate feasibility of a mHealth-based Digital Labour and Delivery Solution (DLDS) for information exchange among healthcare professionals for remote intrapartum monitoring and decision making. 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 an immediate intervention. Throughout labour, all the subjects were monitored using conventional workflows. After each assessment, the in-charge doctor took one management decision from four possible options- (1) "Wait and watch"; (2) "Accelerate the labour"; (3) go for "Assisted vaginal delivery"; and (4) go for "Caesarean section". For each subject, clinical history, examination, and decision details were entered in the DLDS. A doctor located remotely was asked to use the DLDS application to review two records per subject and take one of the four management decisions. The effectiveness of the DLDS for intrapartum information exchange 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. In total, 110 subjects were enrolled for the study. The overall agreement between the two doctors for 220 independent decision points was 0.764 using unweighted Cohen's kappa and 0.723 using weighted Cohen's kappa statistic. The substantial agreement between the two doctors for intrapartum decision making demonstrates the feasibility of the DLDS for remote intrapartum monitoring and decision making. However, further investigation is required to assess effectiveness and safety of DLDS for a general purpose remote intrapartum monitoring.**

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

I. INTRODUCTION

Intense monitoring and prompt decision making is very important during the intrapartum phase due to a short time interval between onset of complications and time to intervene. This is further emphasized by the fact that complications during this phase are responsible for almost 42% of maternal mortality and 23% of neonatal mortality [1]. Effective monitoring during the intrapartum phase needs an effective collaboration between the healthcare professionals. Among various issues, which have an adverse impact on teamwork during delivery, 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 [2].

Poor communication is usually a result of a poor transmission or exchange of information. Paper based methods and telephonic communication are two conventional methods of communication during intrapartum monitoring. However, these methods 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 [3][4].

To improve communication during intrapartum care, many tools such as partograph, digital partograph have been introduced. These are shown to be effective but underutilized due to time constrain and a stiff learning curve [5]–[8]. To standardize telephonic communication, techniques such as Situation–Background–Assessment–Recommendation (SBAR) have been proposed. However, SBAR is a difficult technique to learn and practice, and requires extensive education and training for effective implementation [9]. Moreover, none of these techniques provide an integrated solution for intrapartum monitoring, making them of limited use for a conventional setup.

Structured and instant communication are areas where Information and Communications Technology (ICT) can play a major role. In recent times, mobile devices (smartphone and tablet) 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.

The primary objective of this study was to evaluate feasibility of the DLDS in information exchange among health care professionals for remote intrapartum monitoring and decision making. We had a primary hypothesis that a remote doctor can be equally adept at decision making if he is provided with all the necessary information. The effectiveness of the DLDS was evaluated by comparing the decisions taken by a remote doctor using intrapartum information provided by the DLDS to that of decisions taken by a doctor in a labour room (in-charge doctor).

The rest of the paper is arranged as follows, Section II provides details of the study protocol and statistical methodology. The study results are summarized in Section III. Section IV provides commentary on overall results and their possible implications for clinical practice. Section V

 ISBN: 978-1-61208-688-0

concludes with the most important findings and future work directions.

II. 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 require immediate intervention or where a trial of labour is 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 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.

C. DLDS application

DLDS is 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. DLDS can be used as a stand-alone delivery solution or could be integrated with maternal telehealth platforms such as Mobile Obstetrics Monitoring [10]. 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 is 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, a doctor 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 first record (at the time of admission) and the last record before any active intervention or delivery.

E. Statistical analysis methodology

The decisions taken by both the doctors for each case record 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. The agreement scale proposed by Landis and Koch was used to grade the agreement between the doctors [11].

TABLE I. WEIGHT MATRIX FOR DECISION GRADING

Decision taken by in-charge doctor	***Decision taken by the remote doctor***			
	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

All statistical analyses were done using Microsoft Office Excel-2016 and R (version 3.4.4).

III. 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 due to failure to progress. The rest of the cases were delivered vaginally. None of the 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 between the two doctors 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. 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, small sample sizes in these two categorizes makes it difficult to draw a valid conclusion.

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

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.

IV. Discussion

One very important aspect of the modern intrapartum care is a teamwork approach towards pregnancy and delivery. Despite this, it has been observed that the intrapartum care is still troubled with poor team work. In a study conducted by Guise et al., they observed that less than 50% doctors and less than 37% nurses in labour rooms rated their teamwork as adequate [12], indicating the need to address this issue on a priority basis. The difference in knowledge, skill set and communication style among nurses and doctors has been shown to be responsible for this poor teamwork [13].

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. Telephonic communication is universally available and offers advantages of real time communication. However, it is highly skill and experience dependent [3] and can lead to misunderstanding due to miscommunication [14]. The paper-based methods are simple to follow but are non-standardized, static and prone to manual errors; making them a less reliable medium for information exchange [4][15].

Partograph, a paper-based tool has shown to be an effective method for monitoring labour progress but unfortunately, it is underutilized. Time constraints, staff shortage, lack of knowledge and negative attitude among healthcare providers are some of the obstacles, which are known to hinder an appropriate use of the partograph [5]–[7]. The digital alternatives to partograph are trying to solve these problems by having an easy way of partogram plotting and ability to share it remotely [8]. However, no single solution exists yet, which comprehensively addresses communication needs during intrapartum care. This is the area where ICT devices can play a major role. Emergence of affordable smartphones, increased computational capacity, wider coverage and faster data transfer speed have provided a further boost to the use of the mobile as a platform for delivery of healthcare services. DLDS is one such mHealth solution for intrapartum care.

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. 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.

It was observed that the agreement between the doctors for non-operative mode of deliveries was significantly higher than for operative delivers. This finding is in line with the published literature, where complete agreement for caesarean section decision has been observed to be about 65% [16]. 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.

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 study cases.

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 [17]. 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 [18].

V. 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 doctors.

To conclude, our study has demonstrated a substantial agreement in the decisions taken by a remote doctor using the DLDS and intrapartum decisions taken by a doctor in a labour room. 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.

ACKNOWLEDGMENT

We duly acknowledge help of the staff of JSS, Medical college, Mysuru, India for this study.

REFERENCES

[1] J. E. Lawn *et al.*, "Two million intrapartum-related stillbirths and neonatal deaths: where, why, and what can be done?," *Int. J. Gynaecol. Obstet. Off. Organ Int. Fed. Gynaecol. Obstet.*, vol. 107 Suppl 1, pp. S5-18, S19, Oct. 2009.

[2] J. Commission, "Sentinel Event Alert, Issue# 30, Preventing Infant Death and Injury During Delivery," *Wash. DC Jt. Comm.*, 2004.

[3] P. Giesen *et al.*, "Safety of telephone triage in general practitioner cooperatives: do triage nurses correctly estimate urgency?," *Qual. Saf. Health Care*, vol. 16, no. 3, pp. 181–184, 2007.

[4] T. Schabetsberger *et al.*, "From a paper-based transmission of discharge summaries to electronic communication in health care regions," *Int. J. Med. Inf.*, vol. 75, no. 3–4, pp. 209–215, Mar. 2006.

[5] "World Health Organization partograph in management of labour. World Health Organization Maternal Health and Safe Motherhood Programme," *Lancet*, vol. 343, no. 8910, pp. 1399–1404, Jun. 1994.

[6] T. Lavender, A. Hart, and R. M. D. Smyth, "Effect of partogram use on outcomes for women in spontaneous labour at term," *Cochrane Database Syst. Rev.*, vol. 7, p. CD005461, 2013.

[7] S. Tayade and P. Jadhao, "The impact of use of modified who partograph on maternal and perinatal outcome," *Int. J. Biomed. Adv. Res.*, vol. 3, no. 4, pp. 256–262, 2012.

[8] H. Underwood, J. Ong'ech, G. Omoni, S. Wakasiaka, S. R. Sterling, and J. K. Bennett, "Improving partograph training and use in Kenya using the partopen digital pen system," in *Biomedical Engineering Systems and Technologies*, Springer, 2014, pp. 407–422.

[9] B. B. Pope, L. Rodzen, and G. Spross, "Raising the SBAR: how better communication improves patient outcomes," *Nursing2014*, vol. 38, no. 3, pp. 41–43, 2008.

[10] "Philips - Mobile Obstetrics Monitoring Maternal telehealth software," *Philips*. [Online]. Available: https://www.philips.co.id/healthcare/product/HC867055/mobile-obstetrics-monitoring-maternal-telehealth-software. [Accessed: 09-Jan-2019].

[11] J. R. Landis and G. G. Koch, "The measurement of observer agreement for categorical data," *Biometrics*, vol. 33, no. 1, pp. 159–174, Mar. 1977.

[12] J.-M. Guise and S. Segel, "Teamwork in obstetric critical care," *Best Pract. Res. Clin. Obstet. Gynaecol.*, vol. 22, no. 5, pp. 937–951, 2008.

[13] C. D. Beckett and G. Kipnis, "Collaborative communication: integrating SBAR to improve quality/patient safety outcomes," *J. Healthc. Qual.*, vol. 31, no. 5, pp. 19–28, 2009.

[14] E. Joffe, J. P. Turley, K. O. Hwang, T. R. Johnson, C. W. Johnson, and E. V. Bernstam, "Evaluation of a problem-specific SBAR tool to improve after-hours nurse-physician phone communication: a randomized trial," *Jt. Comm. J. Qual. Patient Saf.*, vol. 39, no. 11, pp. 495–501, 2013.

[15] K. Nagpal *et al.*, "Information transfer and communication in surgery: a systematic review," *Ann. Surg.*, vol. 252, no. 2, pp. 225–239, 2010.
[16] S. A. Pillai *et al.*, "Decisions to Perform Emergency Caesarean Sections at a University Hospital: Do obstetricians agree?," *Sultan Qaboos Univ. Med. J.*, vol. 16, no. 1, pp. e42-46, Feb. 2016.
[17] J. Cowan, "Clinical governance and clinical documentation: still a long way to go?," *Br. J. Clin. Gov.*, vol. 5, no. 3, pp. 179–182, 2000.
[18] J. Stausberg, D. Koch, J. Ingenerf, and M. Betzler, "Comparing paper-based with electronic patient records: lessons learned during a study on diagnosis and procedure codes," *J. Am. Med. Inform. Assoc.*, vol. 10, no. 5, pp. 470–477, 2003.