Partopens at the Point of Care
Evaluating Digital Pen-based Maternal Labor Monitoring in Kenya

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Abstract: The goal of the PartoPen system is to enhance the partograph, a paper-based labor monitoring tool intended to promote timely delivery of quality care by birth attendants in developing countries. The PartoPen digital pen hardware and software system supports partograph use by providing audio instructions for measuring and recording labor progress indicators, real-time decision support based on recorded measurements, and time-based patient-specific reminders for taking measurements. Earlier work found the PartoPen system effective in nursing classrooms at the University of Nairobi (UoN), Kenya where the PartoPen was used to support teaching and training of students in maternal labor monitoring procedures. This paper presents the results of several follow-on studies conducted in the maternity ward of Kenyatta National Hospital (KNH) in Nairobi. Through these studies, we successively refine our understanding of the benefits of PartoPen use in this setting. We also identify and discuss the interrelated factors impacting PartoPen adoption and use in the labor ward at KNH, and review the challenges and opportunities likely to face digital pen deployments in other healthcare settings.

1 INTRODUCTION

The World Health Organization (WHO) estimates that 300,000 women die every year due to pregnancy-related complications, most of which occur in developing countries (World Health Organization 2012). Timely and informed labor monitoring by a skilled attendant can help prevent many of the main causes of maternal death – hemorrhage, infection, unsafe abortion, eclampsia, and obstructed labor (United Nations 2010). Globally, the WHO promotes the paper partograph as an effective and cost-efficient tool for monitoring labor, and preventing obstructed labor and resulting complications. Used correctly, the partograph provides decision support that assists in early detection of maternal and fetal complications during labor. Especially in rural clinics, early detection allows transport decisions to be made in time for a woman to reach a regional facility capable of performing emergency obstetric procedures.

Despite the positive reports of improved maternal outcomes resulting from correct partograph use (Kwast et al. 1994; Mathai 2009; Lavender et al.

2013), several recent studies in Kenya have reported underuse and incorrect use of the partograph at all levels of maternity care (Opiah et al. 2012; Qureshi et al. 2010; Lavender et al. 2011). The well-documented barriers to partograph use include partograph shortage, staff shortage, low partograph knowledge and training, and the perspective that the partograph is time consuming and redundant (Opiah et al. 2012). The goal of the PartoPen project is to mitigate some of the barriers preventing correct and widespread partograph adoption using an interactive digital pen, dedicated pen software, and partograph forms printed with a background dot pattern that is recognized by the pen. Using only the digital pen and the existing paper form, the PartoPen addresses training and resource barriers by providing audio-based decision support, patient-specific reminders, and partograph use instructions. Prior PartoPen work at the University of Nairobi (Underwood, Sterling & Bennett 2013b) suggests that the PartoPen is effective in multiple healthcare settings: initial training, training reinforcement, and use with actual patients. These results motivated two of the studies described in this paper. These studies focus on

populations at two ends of the healthcare spectrum: nursing students with little training or clinical experience using the partograph, and nurse midwives at KNH, who are well-trained and generally have many years of experience using the partograph in the labor ward.

Our previous work examined the effect of PartoPen use on partograph completion in nursing classrooms with third and fourth year nursing students. The results of follow-on maternity ward studies are presented here. In addition, we discuss various environmental factors that led to different outcomes in the two studies.

We first summarize the results from the PartoPen nursing student study, and give an overview of the technological components of the PartoPen system. The remainder of the paper discusses the results of maternity ward studies conducted at KNH in July and August 2012, with follow-up in July 2013.

2 BACKGROUND

2.1 PartoPen Software System

Over the past fifty years, a large body of work on pen-and-paper computing and pen-and-paper user interfaces (PPUIs) has been developed. More recently, digital pens have been used and evaluated for usability and efficiency in the healthcare context both by patients (Lind et al. 2007; Lind et al. 2008), and by nurses (Procuniar & Murphy 2008; Estellat et al. 2008). The key findings in these studies is that digital pen technology is an intuitive and usable technology with great potential, but healthcare-specific digital pen applications must be designed to meet the actual needs of the user. The Livescribe (LS) digital pen technology (Livescribe Inc.) used by the PartoPen system captures pen input and digitizes paper content by using a unique location tracking and page identification technique patented by the Anoto AB group (Anoto).

The current implementation of the PartoPen system uses the LS Echo digital pen running the custom PartoPen software that allows the pen to meaningfully interact with the paper partograph. The Echo pen has a built in microphone, speaker, and OLED display. The pen relies on a rechargeable lithium ion battery, which is advertized to last about 36 hours during normal use. A battery life of 20 to 26 hours has been observed, depending upon the amount of audio played during use. Pens can store between 200 and 800 hours of audio, or the equivalent amount of text data, depending on the pen

model, and all stored data can be downloaded to a desktop computer using a standard micro-USB cable.

One of the goals of the PartoPen system is to enforce birth attendant training on correct use of the partograph, as this has been cited as a significant barrier to consistent use of the form. The WHO partograph user manual, and a local partograph manual issued to clinics by the Kenyan Ministry of Health, are the primary resources for partograph instruction in Kenya. The PartoPen system makes the instructions found in these manuals accessible directly from the partograph itself. The PartoPen uses fixed print "button" regions around the partograph text to provide verbatim audio recordings of the instructions found in the partograph use manuals. Thus, by tapping on these "buttons," nurses and nursing students can get short informational prompts on how to use each section of the form correctly.

One of the most commonly cited barriers to partograph use is the inability to interpret the data plotted on the partograph and take appropriate action. Nursing students and less-experienced nurses often plot the data correctly on the partograph, but fail to derive the meaning of the plotted data, or do not remember what actions to take based on the data that they have plotted. The decision support functionality of the PartoPen addresses these issues by interpreting plotted data based upon page location, and providing real-time feedback on the appropriate actions to take. Currently, the PartoPen provides decision support in three of the partograph sections: cervical dilation, liquor/amniotic fluid, and fetal heart rate.

The labor ward at KNH delivers approximately 1000 babies during the "busy" months from October to March, or roughly 34 babies every day. On average there are 4-6 nurses working at a time, and based on survey data collected at the end of the PartoPen study, nurses on average are responsible for 5-7 patients during a day shift and 7-10 patients during a night shift. The WHO recommends a maximum ratio of one nurse to three patients to ensure compliance with partograph completion protocols. In the survey, nurses nearly unanimously reported that staff shortage is the most common reason for low partograph completion rates. While the PartoPen does not replace nurses or supplement the shortage of nurses in the labor ward, it does provide a reminder system intended to help busy and tired nurses keep track of when patients need measurements taken.

2.2 PartoPen Nursing Student Study

Ninety-five nursing students in their third and fourth years of study at the UoN School of Nursing Sciences participated in the study. Students were asked to complete a partograph worksheet, which consisted of two patient case studies and two blank partograph forms printed with the dot pattern. The students recorded the patient data on the blank partograph forms as if they were actively monitoring that patient during labor. In each worksheet, students received two of three possible patient case studies. The three case studies represent three possible labor outcomes. Mrs. A's data represents an uncomplicated, timely labor that progresses without medical intervention. Mrs. B's data illustrates a case of prolonged or obstructed labor. Mrs. C's labor progression data illustrates an increasing number of complications, including fetal distress, and ultimately results in a cesarean section.

The students were first divided into three groups. Group 1 was the control group, and Groups 2 and 3 were the intervention groups. Group 1 students completed a partograph worksheet task with a PartoPen in "silent logging mode," and received no instructions on how to use the technology. Group 2 completed the same worksheet task, but used a fully functional PartoPen in "use" mode. The PartoPen software in "use" mode for the student pilot has two main components: instructions and decision support. Group 2 received no training on how to use the technology. Group 3 received a fully functional PartoPen in "use" mode and a 15-minute introduction and demonstration of the PartoPen system before completing the partograph worksheet task.

Using an unpaired t-test, the difference between Group 1 (M=.520, SD=.141) and Group 3 (M=.722, SD=.089) for the patient case study Mrs. C, a prolonged labor resulting in a CS, was found to be significant; $t(8)=2.709$, $p=0.0267$. These data suggest that for more challenging or complex labor cases, the availability and utilization of the PartoPen instruction prompts promotes more accurate form completion.

After each group completed the worksheet task, students were asked to participate in a short focus group session. Students unanimously reported that plotting contractions was one of the most difficult sections of the partograph, because both duration and frequency are plotted together using a combination of bar charts and coloring patterns. Students also reported unanimously that plotting descent of the fetal head was particularly challenging. Difficulties plotting descent of the fetal head can also be attributed to having to plot on the same graph as another measurement (cervical dilation), but may also be due in part to the nursing school transitioning to a different partograph version that requires users to plot the descent in increments of one instead of two, and on the left side of the graph instead of the right.

The completion results of the 'contractions' section of the partograph show improvements in all three case studies (Mrs. A, B, and C) between groups that did and did not use the PartoPen. There was a statistically significant improvement in contraction plotting on the Mrs. C case study between Group 1 (M=.513, SD, .232) and Group 3 (M=.803, SD=.139); $t(8)=2.399$, $p=0.0433$.

'Descent of fetal head' measurements also showed a significant improvement on the Mrs. C case study between Group 1 (M=.337, SD=.152) and Group 2 (M=.585, SD=.162); $t(10)=2.699$, $p=0.0223$. In addition, there was a very significant improvement on descent plotting on the Mrs. C case study between Group1 and Group 3 (M=.705, SD=.137); $t(8)=4.028$, $p=0.0038$.

The UoN PartoPen study indicated that PartoPen use in classrooms can improve students' ability to correctly complete a partograph form. The study results also suggest that significant PartoPen training is not required to achieve these benefits. A significant increase in partograph completion and accuracy was observed with minimal prior training, due to the intuitive design, push-based functionality, and the enhancement – rather than replacement – of the current paper-based system.

3 MATERNITY WARD STUDY

The follow-on PartoPen studies in the maternity ward at KNH examined the impact of the digital pen software system on partograph completion by nurse-midwives monitoring patients during actual labor. The partograph used in this study is pictured in Appendix A. The first study was conducted in July-August of 2012 at Kenyatta National Hospital. The study was designed as a pre- and post study, which compared partograph completion rates for partographs completed in June (without the PartoPen system) and in August when the PartoPen system was in use by nurses.

3.1 Methodology

Currently KNH evaluates partograph completion

using a rubric with four options – "complete," "incomplete," "correct," or "incorrect" – boxes for each partograph category (fetal heart rate, moulding, cervical dilation, etc.) Due to the wide range of variation in how partographs are used and completed, this basic evaluation rubric does not correctly capture the actual completeness of the partograph, or the real usefulness the data recorded on the partograph. We therefore created a new rubric that would better assess these measures. This rubric is built upon the basic tenants of the evaluation tool used by KNH. The rubric has grading criteria for each partograph category, including a separate set of grading criteria for the labor summary printed at the bottom of each partograph. For each partograph category there are three grading criteria: (1) measurements recorded, (2) symbols correct, and (3) spacing correct. The total possible value for each of these grading criteria is determined by the time between patient admission and delivery.

Previous efforts to evaluate partograph completion required researchers to continuously observe nurses during labor monitoring to assess partograph completion (Rotich et al. 2011), or researchers were required to use a coarse-grained categorization scheme similar to the original KNH rubric (Khonje 2012).

The new rubric also has some limitations. Chief among these is the fact that the time of admission is used to determine how many measurements are expected on the partograph form. The time of admission, however, does not always accurately reflect when the woman went into active labor or when the partograph was started.

All of the partographs collected during the study were first categorized by delivery mechanism – spontaneous vaginal delivery (SVD) and cesarean section (CS). The CS deliveries were further categorized into emergency CS (EmCS) and "other", which includes voluntary CS and CS due to previous CS scars. Deliveries of twins, triplets, or deliveries lasting less than one hour were noted among the SVD partographs, but not included in the data analysis because partographs a) are not designed to monitor multiple births, and b) do not provide beneficial monitoring for labors that are less than one hour in length.

3.2 Quantitative Results

Initially all of the collected partographs from June (369) were compared to all of the collected partographs from August (457). This blanket analysis of partograph completion rates between June and August attempted to capture any broad improvements that may have occurred due to researcher presence, or a general increase in interest and attention to the partograph because of the PartoPen study taking place. These results are captured in a previous paper (Underwood, Sterling & Bennett 2013a), and briefly summarized below.

3.2.1 Phase 1 Data Analysis Summary

In the initial data analysis process, the collected partographs were graded and checked by two pairs of research assistants according to the new evaluation rubric. Each partograph received two scores: a composite completion score and a summary score. The composite score was calculated by dividing the number of points received by the total number of points possible for all three grading criteria (mark existence, correct mark symbol, and correct mark spacing) for each partograph section (fetal heart rate, cervical dilation, etc.). The summary score reflects the completion percentage for the partograph summary section at the bottom of the form, which summarizes the labor (and is usually completed after a patient delivers).

Based on this initial analysis, there were no statistically significant improvements in the composite scores between June and August partographs. However, there were improvements in the summary scores for both SVDs and CSs. This result can be attributed to several possible factors. First, the partographs used in June were slanted and blurred due to frequent photocopying, whereas the partographs used in August were printed individually (to assure the unique dot pattern on each form). This made the August partographs significantly easier to read and, presumably easier to complete. Second, the improvement in summary scores was likely a result of the increased awareness and underscored importance of the partograph that occurred during the PartoPen study.

The lack of improvement in completion rates for the overall composite partograph scores in the presence of the increased focus on the partograph is likely due to the impact of understaffing. Understaffing thwarts completing the graphical portion of the partograph because the ratio of nurses to patients (often between 1:5 and 1:10) does not allow for regular half-hour measurements to be taken for each patient. The PartoPen system cannot replace trained staff members, and does not directly address the understaffing barrier to partograph completion.

The data from the broad comparison of June and

August partographs suggest that the PartoPen does not have an overall impact on partograph completion, at least not in facilities like KNH, which have highly trained and experienced, but critically over-worked, staff.

3.2.3 Phase 2 Data Analysis

After the initial broad data analysis, a more fine-grained analysis was performed on the PartoPen data to ascertain if and how the PartoPen functionality impacted partograph completion rates. Partographs completed in June were compared to August partographs that were *actually completed* with the PartoPen. The PartoPen was used to complete 48 of these partograph forms. PartoPens were only given to nurses at KNH during the study, which excluded the nursing students who were actively working in the labor ward as part of their clinical rotation. Student-completed partographs in August, which were not completed with a PartoPen, were excluded from Phase 2 analysis. In addition, many partographs were only partially completed with the PartoPen, due to nurse rotations and patient handoffs. These partially completed partographs were also excluded from Phase 2 analysis.

The comparison of all the partographs completed with PartoPens versus the August partographs not completed with the PartoPens versus all of the June partographs is represented in the Figure 1. This histogram illustrates that August partographs completed with the PartoPens never received a completion score lower that 25%, whereas both June and August partographs completed without the PartoPen did. Additionally, the August partographs completed with the PartoPen had the highest
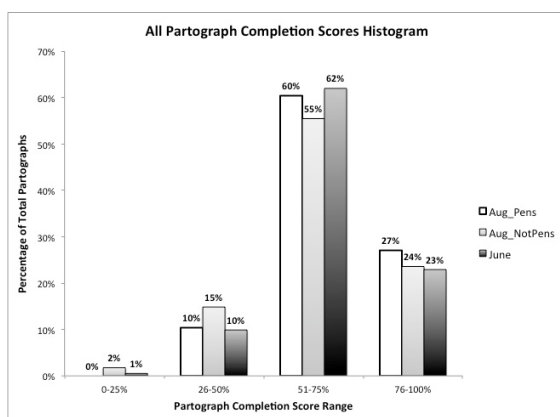

Figure 1: A histogram of partograph completion scores for August partographs completed with a PartoPen, August partographs not completed with a PartoPen, and June partographs.

percentage of partographs in the 75-100% completion range.

4 2013 FOLLOW-UP STUDY

At the conclusion of the PartoPen maternity ward study, the nurses and hospital staff had successfully incorporated the PartoPen system into the daily operations of the labor ward. The system in place at KNH at the end of the study included 20 PartoPens, a printer capable of printing the dot pattern partographs, PartoPen chargers, and extra pen caps and ink replacements. Nine months after the completion of the 2012 PartoPen maternity ward study, a follow-up study was conducted with KNH nurses to assess the performance and impact of the PartoPen system.

Upon returning to the KNH labor ward in May 2013, researchers found that all 20 of the PartoPens were accounted for, 19 out of the 20 PartoPen were functional, and over 600 digital partograph records were present on the PartoPens ranging from September 2012 to April of 2013 (the printer used to print dot-patterned partographs failed in April 2013, and replacement parts were not readily available in Nairobi). During the May 2013 visit, PartoPen researchers identified a local printer model alternative and worked with hospital IT staff to establish a recurring printer toner order, so as to remove this responsibility from the already busy nurses and record-office staff in the labor ward.

4.1 Methodology

During the May 2013 visit, PartoPen researchers surveyed KNH labor ward nurses regarding their impressions of PartoPen deployment and use. Twenty-six nurses completed a paper survey about the PartoPen and its affect on labor ward operations and patient care.

The paper survey consisted of nine questions (see Appendix B); four YES/NO questions, two Likert scale questions, and three free response questions. The survey also included basic demographic information, and a rank-order question where nurses ranked the importance of the partograph sections. The surveys were completed during morning patient handoff. Nurses took an average of 15 minutes to complete the survey, and the nurses were not compensated for their time.

4.2 Follow-up Survey Results

Thirteen of the 26 nurses who completed the survey felt they were 'experts' using the PartoPen system. The majority of the nurses (19 out of 26) used some combination of partograph information and other patient information to make decisions about patient care. The nurses were asked to rank in order of importance the different sections of the partograph as they relate to providing quality patient care. Nine nurses ranked patient name and age as the most important section of the partograph to complete. Eight nurses ranked fetal heart rate as the most important section of the partograph, and seven nurses ranked the partograph sections sequentially (i.e., the most important section is the topmost section of the form, and the least important is the bottommost portion of the form). One nurse ranked contraction frequency as the most important, and one nurse ranked cervical dilation as the most important section of the partograph to complete. The responses from the survey suggest that certain information on the partograph is more useful for making critical decisions about patient care, which may indicate that a simplified and restructured form that highlights these sections (and makes them easier to complete) could be useful in this setting. Nurses largely prioritized patient information and fetal heart rate as the most important portions of the form. In the PartoPen study, some of the qualitative feedback received by nurses indicated that using larger boxes for information entry for these sections considerably improved the usability and readability of these critical pieces of information.

The survey also asked nurses to identify if there are certain kinds of labor or patients who do not need a partograph. Twenty of the 26 nurses said that there were patients who do not need a partograph during labor. Elective cesarean sections, false labors, and patients who arrive already in the second stage of labor were the most common responses for labors that do not require a partograph to monitor labor progress. Elective cesarean sections are scheduled in advance and are categorized separately from emergency C-sections that happen as a result of complications during labor. Additionally, Kenyatta National Hospital, as the leading referral hospital, receives a very high volume of patients who are in the second stage of labor. Although KNH administrative policies require that a partograph be used during all labors without exception, staff shortages make prioritization necessary when deciding to begin or continue a partograph for a patient. Since KNH is a referral hospital, many patients arrive late in labor in poor condition, and completing paperwork or a partograph is not the highest priority of hospital staff. The result is blank or retroactively completed partographs.

Nurses were also asked to identify patients and labor types that benefit the most from being monitored with a partograph. Nurses were allowed to circle more than one labor type out of SVD, CS, IUFD, Referral, and 'Other'. Twenty-three out of 26 nurses said that spontaneous vaginal deliveries (SVD), which are often categorized as 'normal' labors, benefit the most from correct partograph use. Eleven out of 26 nurses circled CS, emergency cesarean sections, as benefiting the most from partograph use, and 7 out of 26 nurses circled 'Referral'.

The survey asked several PartoPen-specific questions, including whether the nurses had observed any changes in the labor ward because of the PartoPen. This question was included in the survey to follow up on qualitative observations and discussions at the end of the 2012 studies that suggested labor ward nurses were feeling an increased sense of pride in their job because of the interest of senior hospital staff, and reliance on labor ward nurses to explain the project and demonstrate its functionality. Additionally, only labor ward nurses were given PartoPens, and this sense of privilege was mentioned several times by nurses as rewarding. Twenty-four of the 26 nurses said 'yes', there had been changes in the labor ward because of the PartoPen. The majority of the changes nurses described related to the reminder functionality of the PartoPen. Nurses frequently noted the reminders being effective for providing more timely care and making patient care more efficient. Better decisions and easier chart interpretation were also noted as significant changes resulting from PartoPen use in the labor ward.

4.3 Secondary Data Analysis

Based on the data from the 2013 surveys, the data from the 2012 maternity ward study was re-examined, as follows: First, only the SVD partographs were included, as the majority of nurses indicated that SVD patients benefit most from partograph use. In addition, partograph sections that nurses deemed most important (i.e., (patient information and fetal heart rate) were examined individually.

The SVD partographs were analyzed in three categories: August SVDs completed with the PartoPens, August SVDs completed without the

PartoPens, and all of the SVDs from June. Using the same grading and evaluation rubric, these partographs were analyzed with respect to completion. The results of this analysis are shown in Figure 2. Frequency in this histogram is represented as a percentage of the total number of partographs present in the sample (37 August partographs completed with the PartoPens, 206 August partographs completed without the PartoPens, and 153 partographs completed in June). The histogram illustrates that August partographs completed with the PartoPens never received below 25% completion, and this set had the highest percentage of partographs in the 75-100% range.

The same set of SVD partographs was then analyzed, looking specifically at the completion of the 'patient information' and 'fetal heart rate' sections. While fetal heart rate completion did not change significantly between the three groups, a significant difference was observed in patient information completion between August PartoPen SVDs (M=.949, SD=.086) and June SVDs (M=.882, SD=.152) using a paired t-test (t(188)=2.6178, p=.0096). This difference may be attributable to several factors, including the improved readability and larger space for the patient information fields on the PartoPen version of the partograph form.
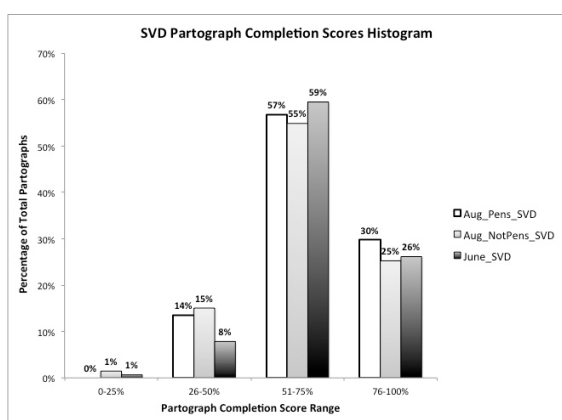
Figure 2: A histogram of SVD-only partograph completion scores (for August partographs completed with a PartoPen for spontaneous vaginal deliveries only, August partographs completed without a PartoPen for SVDs only, and June partographs for SVDs only).

5 DISCUSSION

The results from the maternity ward studies do not generally exhibit significant differences in partograph completion rates between partographs completed with the PartoPens and those not completed with the PartoPens. In retrospect, this result is not surprising. The PartoPen system was designed to address training barriers that have been cited as significant obstacles to correct partograph use. However, the PartoPen system was deployed at Kenyatta National Hospital, one of the leading training and teaching facilities in Kenya. KNH has a highly trained and knowledgeable staff who are less likely to benefit from the training re-enforcement aspects of PartoPen use. The other cited barriers to partograph use, including staff shortages and lack of supplies, are not directly addressed by the PartoPen system, thus at KNH, any training reinforcement benefit the PartoPen provided was overshadowed by other barriers.

The positive results in the nursing student study demonstrate that the PartoPen is beneficial for partograph training for less-trained staff or for students learning how to use the partograph. In a controlled environment like a classroom where the primary focus is on the task of completing a form rather than delivering a baby, the PartoPen's training reinforcement and decision-support functionality are fully utilized. In the chaotic and understaffed environment of the labor ward at KNH, the primary focus is on patients, not on paperwork, thus the design objectives of the PartoPen system did not align well with the primary focus of the KNH nurses.

The next iteration of the PartoPen project will be deployment at more rural and local levels of maternity care, where nurse training, rather than staff numbers and supplies, is the more problematic issue. The primary contributions of the PartoPen study in the maternity ward at KNH include nurses' reflections on PartoPen usability, nurses' perceptions of useful versus complete partographs, and initial data on the durability and infrastructure requirements of the PartoPen system, which can be used in future deployments of the platform in other labor wards.

From interviews with the nurses and researcher observations, the reminders issued by the PartoPen had the most impact on nurse behavior, although this impact did not translate into increased partograph completion, for the reasons described below. The partograph used in the study was supplemented with PartoPen Reminder ID boxes at the very bottom of the form. Nurses were instructed to use these boxes to record a memorable patient code, such as a patient's initials or the room number where the patient was located. This patient code would be displayed on the OLED display on the PartoPen when the reminder for that patient sounded. The goal

of the reminder system was to ensure timely patient checkups by nurses who are busy, distracted, or simply have forgotten to check on one of their many patients. However, when the ratio of nurses to patients is between 1:7 and 1:10, even if a nurse has correctly recorded a patient code and receives the patient's reminders, she may be assisting with another labor, checking on another patient, etc. Many of the nurses reported receiving the reminders but being unable to act on them because they were already involved with a different patient. Additionally, the design of the system was not as helpful to nurses who had their hands busy, as the patient code was displayed textually on the screen, and nurses were often unable to stop what they were doing to look at the pen and read the patient reminder ID.

6 CONCLUSIONS

The initial objective of the PartoPen maternity ward studies was to examine the impact of digital pen technology on *partograph completion*. This objective assumed that a primary barrier to partograph completion was a lack of training and knowledge on how to complete and interpret the form. However, the highly skilled staff at KNH did not lack in training or knowledge, but rather, suffered from staff and resource shortages, which the PartoPen was not designed to address. Despite the disparity between the study goals and observed study site realities, several important observations were made that may contribute to future work in this area.

First, every clinic or hospital has a unique set of problems, personnel and procedures, which have to be identified and addressed during both study design and implementation. The PartoPen maternity ward study design did not adequately account for the myriad confounding factors present at KNH, including under-staffing issues, different birth rates between months compared, and the presence of (different groups of) nursing students in the labor ward during the intervention month, but not the control month. Unlike the PartoPen nursing student study design, the maternity ward study was not designed such that *only* the affect of the PartoPens on partograph completion could be measured. In one analysis, study results were evaluated assuming an experimental study where nurses were given the intervention (the PartoPen) and the nursing students present in the labor ward were the controls. This was not the ideal study design, as the experimental and

control groups were not well matched in terms of training, background, or experience. A more appropriate study design for this environment would be a paired comparison of individual nurses' performance on partographs for similar labor types with and without the PartoPen during comparably busy shifts.

The study design that was used – a combination of qualitative and quantitative data collection – illustrates a disparity between the data from nurse surveys and research observation and the data from the partograph completion evaluation. When surveyed, all of the nurses reported that they considered partograph information to be important, and that they relied upon this information. Interviews with nurses also revealed that nurses considered the partograph is an essential tool in the labor ward. However, the low partograph completion scores, regardless of the PartoPen intervention, suggest that the partograph was often under-utilized, filed out retroactively, or filled out incompletely. This result is not indicative of a lack of diligence or aptitude, rather a lack of adequate staffing. Thus, partograph completion rates should not be routinely equated with quality of care, particularly at a short-staffed referral facility. It would therefore be premature to promote the partograph universally without conducting large-scale studies on the direct association between partograph use and maternal and child outcomes, which account for environmental and social circumstances unique to the study site.

Second, health informatics interventions, especially in developing countries, are often consumed by the technological aspects of the project. We sometimes fail to recognize the benefit of addressing immediate and simple issues, which do not necessarily require technological intervention. The qualitative feedback received by nurses indicated that the cleaner PartoPen form with larger boxes for information entry considerably improved the usability and readability of the form. The cleaner form was simple to produce within the existing workflow and with existing equipment, and could have been done independently of the PartoPen project.

Finally, the PartoPens deployed at KNH were successfully used and sustained for over nine-months of continuous hospital use. This illustrates the robustness of the system, as well as a willingness among nurses to use the PartoPens on a daily basis. The PartoPen maternity ward study helped identify the environmental and physical challenges present in the KNH labor ward, and illustrated both the

challenges and opportunities that arise when deploying a digital pen software system in a maternity ward setting. The results of this study are encouraging for the continued and expanded use of digital pen systems in healthcare, and stress the need for more in-depth and well-designed studies in this area.

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APPENDIX A

APPENDIX B

KNH PartoPen Study – Participant Survey – June 2013

Please provide answers for the following questions:

Age: _____   Gender: _____

1) Did you participate in the PartoPen study in July and August 2012?   YES   NO

2) What is your level of experience using the PartoPens? (circle a choice below)

    1   2   3   4   5
No experience   Expert

3) How much do you rely on the partograph to make decisions about patient care? (circle a choice below)

    1   2   3   4   5
I don't use partograph   I **only** use partograph
 information at all   information

4) Please number the following partograph sections in order of importance from 1 to 24, where 1 is the first thing you look at on a partograph to make patient care decisions, and 24 is the partograph section that you need the least to feel confident making patient care decisions. *(Partograph sections were listed below in original survey, but space constraints prevents us from listing them here.)*

5a) Are there certain patients that do not need a partograph?   YES   NO
5b) If yes, what type of patients do not need a partograph?

6a) What kind of labors/births benefit the most from correct partograph use? (circle all that apply)

SVD   CS   IUFD   Referral   Other?

6b) For the answers you circled in 6a, please explain why these types of births benefit the most from correct partograph use.

7a) Have there been any changes in the labor ward because of the PartoPen?   YES   NO
7b) What are they? How did they affect you?

8a) Have there been any problems with the PartoPen?   YES   NO
8b) If yes, what are they? How did they affect you?

9) Now that you have used the PartoPens for several months, what would you like the next steps to be in the project? (Please list any other comments about the PartoPen project here).