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Results: Chart completion rate was 47.5% in the old charts but increased to 65% in the new DPPS. This implied an improvement of 17.5% in chart completion rate. However, DPPS documentation had higher effects in postoperative documentation (mean difference 20%) as compared to preoperative documentation (mean difference 10%). The new DPPS however had marginal effects on intra operative documentation.

Conclusion: A well-structured obstetric anesthetic chart improved the quantity of documentation. The digital pen and paper system showed potential value as a data-collection tool in low resource setting.

1. BACKGROUND

The anaesthetic chart is an essential part of the medical record.¹ The volume of data which may be collected has greatly increased, making the age-old paper record inadequate.^{2,3,4} In Zimbabwe, anaesthetic data is collected manually with one generic

chart for all subspecialties. The Division of Anaesthesia provides anaesthesia service in Parirenyatwa Group of Hospitals (PGH) and Harare Central Hospital (HCH), two tertiary level hospitals of 1000 beds each with high volume obstetric work of between 300-500 Caesarean sections performed monthly. In obstetric anaesthesia, data is increasingly becoming an important factor in improving maternal outcomes. Safe practice and accurate information management surrounding Caesarean section has a meaningful role to play in improving maternal mortality.^{5,6}

Current Anaesthesia Information Management Systems (AIMS) make electronic charts more complete with accurate data collection.^{7,8} There is currently a strong move supporting automated anaesthesia records to facilitate “Big Data” research.⁹ However despite these advantages, AIMS implementation has met with resistance from policy makers due to its expense, the steep learning curve and cumbersome equipment.^{10,11} Pen and paper remains the most cost-effective, efficient and easy way of acquiring data in low-resource settings. Going fully digital in this context will have to be a gradual patchwork as departments build up electronic capabilities and prepare clinicians. A compromise is therefore required to improve efficiency of data capturing, while allowing institutions to transition towards AIMS. Digital pen and paper system (DPPS) may provide a low-cost approach to automating paper based processes without disturbing the simplicity of using ordinary pen and paper.^{12,13} However, there is a paucity of published research on the use of the DPPS in anaesthesia, especially in obstetrics, with a few published studies identifying its potential use in clinical practice.^{15, 16-21} Overall, few studies have assessed the adequacy of anaesthetic record-keeping, with some illustrating that documentation is generally inadequate.^{7, 21,22}

In Zimbabwe, the anesthesia chart has undergone little change over a period of more than twenty years. A revised digital chart could improve data capturing and retrieval. This article reports on the process by which a new obstetric anaesthetic chart was designed for two teaching hospitals in Zimbabwe.

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a) Aims

The aims of this study were to revise current anaesthesia charts for obstetric use and to determine whether introduction of the new chart with use of the DPPS would lead to superior data quality and quantity. The hypothesis was that peri-anaesthetic documentation in the obstetric population would be superior with the use of the new chart and DPPS.

b) Digital pen and paper technology

Digital paper is ordinary printer paper which has a pattern of microscopic dots printed on it by a laser

printer. The digital pen utilizes the dot pattern to decipher its location on the page. The pen's built-in infrared camera records the coordinates of the handwritten strokes during writing. The charts are kept in the pen's memory until they are routed to remote servers. Routing happens by putting the digital pen in a cradle fastened to a network-connected Personal Computer (PC) or via a Bluetooth-enabled mobile communication device. The handwriting is then changed to digital text and an image of the handwritten form immediately becomes available. Figure 1 shows the basic components of a digital pen and paper system.

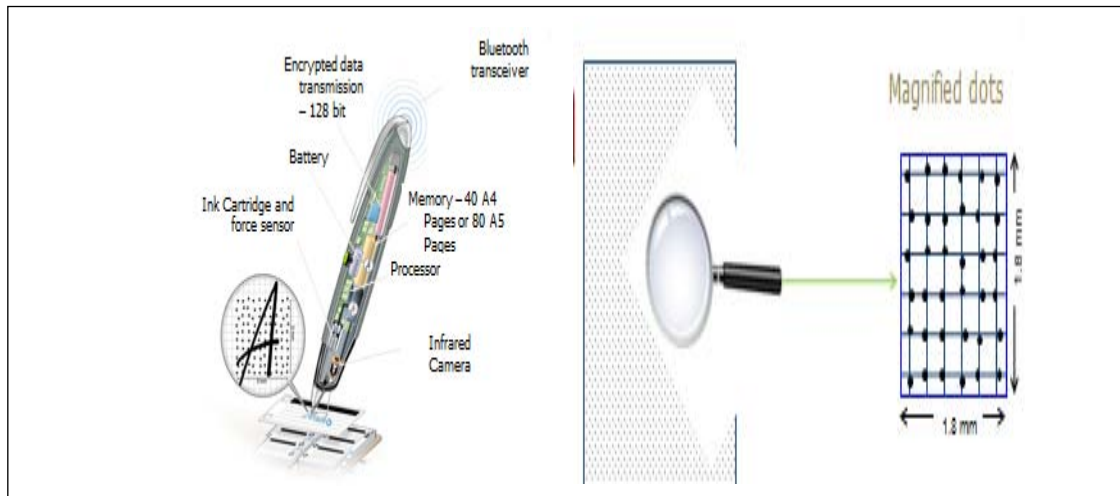


Figure 1: Digital pen with its components (left) and Digital paper with printed microdots (right)

II. METHODS

a) Study Design

This study was prospective interventional study involving new DPPS charts and old manual charts.

b) Sample Size and Sampling Procedure

A study by Kylie-Allen et al (1) found that traditional old charts had ANZCA compliance score of 81.6% while electronic data capture had compliance of

88.6% with a mean difference of 7.1% in comparison with handwritten records. To test the efficacy of the DPPS, a non-inferiority hypothesis was assumed that DPPS would lead to non-inferior data quality and quantity of the obstetric anesthesia chart as compared to manual documentation. Therefore the sample size used in this study was given by non-inferiority formula (2) as shown below:

$$n = \frac{(p_1(1 - p_1) + p_2(1 - p_2)) \times (Z_{1-\beta} + Z_{\alpha/2})^2}{(p_1 - p_2)^2}$$

Where n = sample size required

p_1 = DPPSS compliance with ANZCA (88.6%)

p_2 = Hands written manual documentation compliance with ANZCA (81.6%)

Z_β = Desired power (0.84 for 80% adopted for this study)

$Z_{\alpha/2}$ = Desired level of statistical significance. (1.96 for 95% adopted for this study)

$$n = \frac{(0.886(1 - 0.886) + 0.816(1 - 0.816)) \times (0.84 + 1.96)^2}{(0.886 - 0.816)^2} = 391.6 \approx 392 \text{ records}$$

However, the researcher sampled 432 records (216 record for old charts and 216 records in new charts using DPPS) inclusive of 10% attrition rate.

c) Data Collection Procedure

Data was collected from anaesthetic charts, that is, the new digital charts on one arm and the old charts as the other arm. Since only one pen was available at

each hospital for the study patients were recruited in this manner: from 0800-1400hrs patients were recruited consecutively for each theatre and then from 1400hrs patients were recruited into those using the new and old charts on alternate days.

Members of staff in two departments were trained via demonstrations on use of the new sheet and pen. For this study, the Live Pen™ 1 pen (Anoto DP-201: Sweden supplied by Xcallibre, Durban, South Africa)

was used (Figure 2). This was commercially acquired independently and Xcallibre were not involved in the study. A one-week pilot period was used to familiarize staff and address technical glitches. During the study, the researcher was available for troubleshooting and there were information booklets in each theatre at all times. XCallibre's cloud system provided back-up and technical support in case of system failure.



Figure 2: The digital pen with cap off switching it on

The new system was tested alongside the old charts for a month based on the ANZCA scoring system (Table 1). The sheets were assessed for completeness using a scoring system (Table 1) based on the Australian and New Zealand College of Anaesthetists (ANZCA) PS06 Anaesthesia recommendations and a tool developed by Elhalawani.⁴ This was also combined

with the ASA House of Delegates Statement on the documentation of anaesthesia care.²⁴ Phase I results were used to further adapt the tool for the study. The scoring system rated charts from 0 to 40. A score of zero was given to a blank chart, and 40 were given for a form 100% complete.

Table 1: Scoring System for determining form completion

Anesthetic Documentation	Data field	Requirement	Maximum score
Pre-operative Encounter	Patient's name, hospital number, gender, weight	Each to be documented in both the pre-op and intra-op document	4
	Date	On pre-op and intra-op encounters	1
	Name of anesthetic providers and signature	On pre-op and intra-op encounters	1
	Procedure	Brief description on pre-op and intra-op encounters	2
	Medical status	ASA grading	1
	Medications and allergy	On pre-op assessment	1
	Previous anesthesia	List and complications (or none)	1
	Airway, dentition and GORD (Gastro-oesophageal reflux disease)	Airway: Mallampati score, thyromental distance	3
	Premedication	Dentition: any loose, false or broken teeth	1
	Anesthetic plan	If appropriate	1
	Risks	Brief description	1
	Consent	Brief description	1
	Fasting	Including for regional anesthesia	1
		Fasting instructions	1
Intra-operative Encounter	Anesthetic machine check	Full details (general and regional)	1
	Anesthetic technique	Time and dose of administration	1
	Drugs administered	Degree of difficulty, grade view, Size and type	1
	Airway	Breathing systems, flows and mode of ventilation	2
	Breathing system	List details (e.g. size and site of Central venous catheter Intra-arterial line,)	1
	Monitoring method	Site, size of IV access. Type and volume of fluid	1
	Vascular access and IVT	Must be documented	1
		Timing and doses	1

	Significant blood loss Vitals recorded in full Drugs administered and Antibiotics Level of block Regional anesthesia documentation	Full details	1 4 1 1 2
Post-operative Encounter	Post-op recovery analgesia Oxygen therapy Post-op ward analgesia Post-op fluid and transfusion orders PONV (post-op nausea and vomiting) protocol	Pain protocols when appropriate Where appropriate Documentation on either operative record or medication chart To cover 24 hours Where appropriate	1 1 1 1 1

d) Ethical Consideration

Ethics approval for the study was granted by the Harare Central Hospital (HCH) ethics committees [(HCH Ethics Committee and Joint Research Ethics Committee JREC/Ref #14/46)]. Since records were uploaded onto standard Android platform, data was encrypted to protect patient identity. Only the researcher and two consultant anaesthetists had password-protected access to the files for editing and data cleaning. The database was backed up by XCallibre's cloud based system.

e) Data Analysis

Data was analyzed using Stata Version 11. Descriptive statistics such as means and standard deviation was used to describe the completeness

scores in the two types of charts. Mann Whitney U and Friedman tests were used to compare completeness scores. Findings were presented at 95% confidence interval using graphs.

III. RESULTS

a) Anaesthetic Documentation Completeness

An audit in the anaesthetic records indicated that in all cases, postoperative records had the highest level of completeness while intraoperative records had the least documentation completeness. There was significant variation in level of completeness between preoperative, intraoperative and postoperative documentation (Friedman test: $\chi^2 = 194.6$, degrees of freedom = 2, p-value = 0.000).

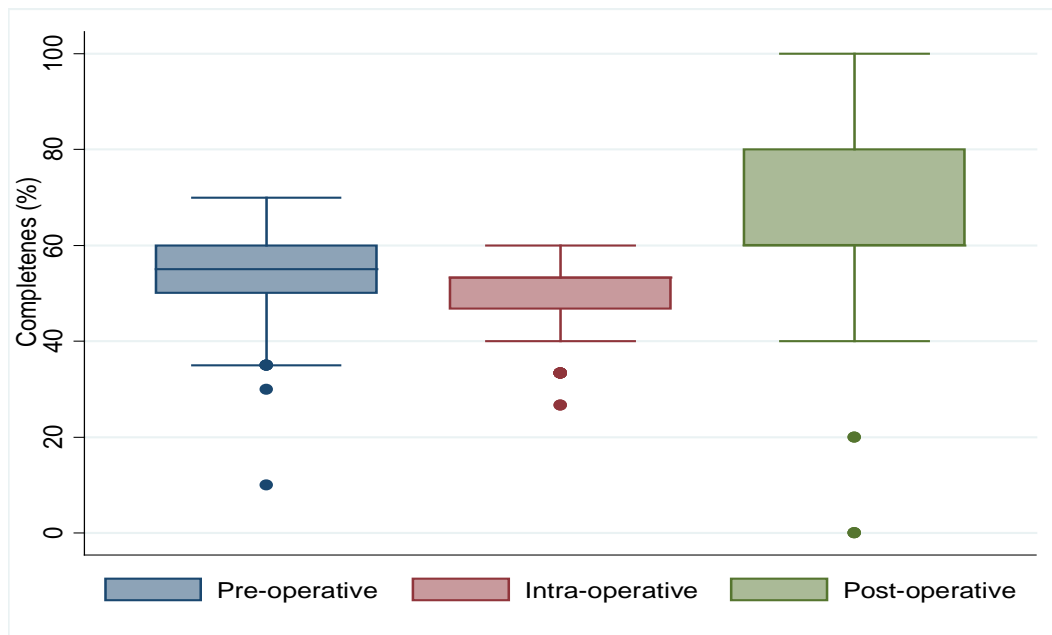


Figure 3: Anaesthetic Documentation Completeness

b) Preoperative Completeness

As shown in the figure below the median preoperative completeness of the old charts was 50%

while the median preoperative completeness of the DPPS charts was 60%. None of the charts had a preoperative completeness of more than 70%. However,

it was found that on average DPPS charts had significantly (Mann Whitney U test: $Z = -8.845$, $p\text{-value} = 0.000$) higher preoperative completeness

as compared to the old charts. This showed that the new DPPS system enhanced preoperative documentation by 10%.

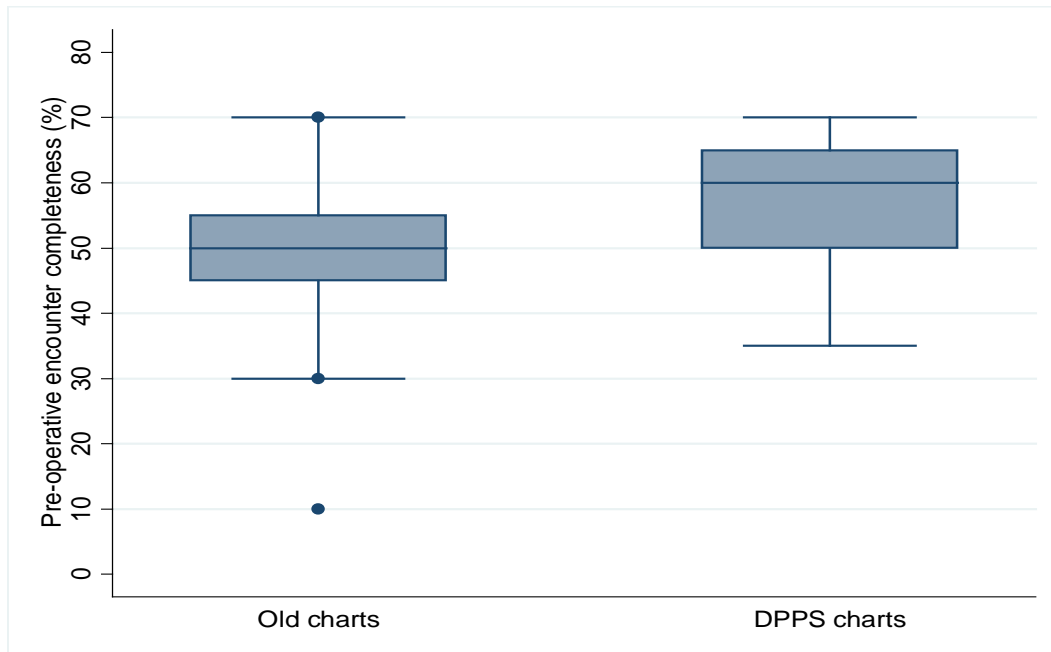


Figure 4: Preoperative Completeness

c) Intraoperative Completeness

As shown in the figure below the median intraoperative completeness for both old charts and DPPS charts was 53%. None of the charts had a completeness of more than 60%. The intraoperative

completeness in DPPS charts however was significantly (Mann Whitney U test: $Z = -4.325$, $p\text{-value} = 0.000$) higher than old charts. This showed that DPPS marginally contributed to enhancement in intraoperative documentation.

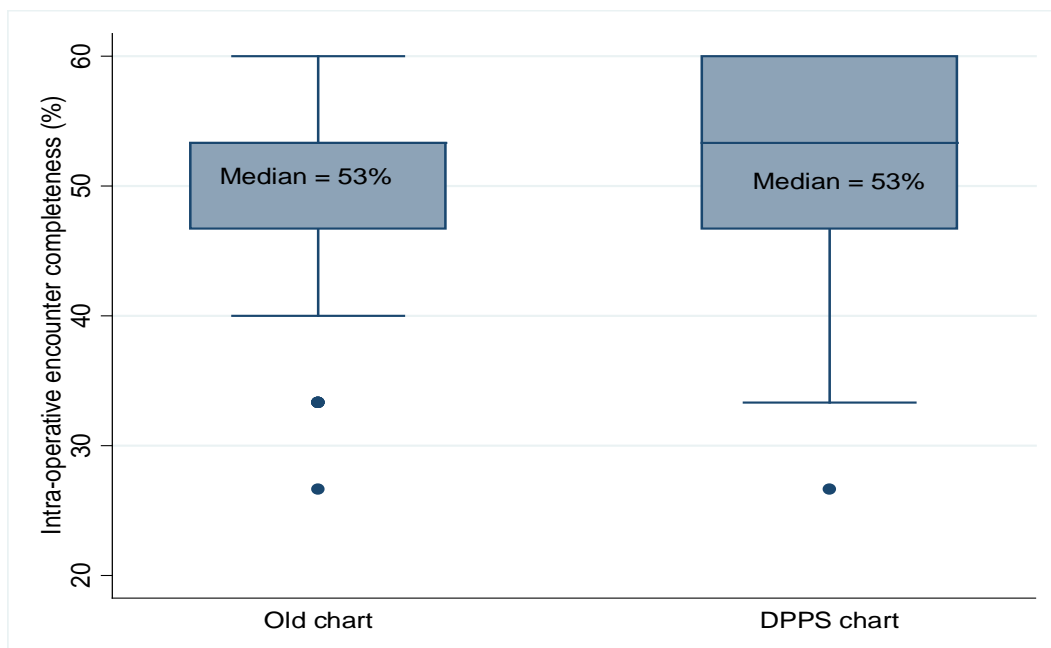


Figure 5: Intraoperative Completeness

d) Postoperative Completeness

As shown in the figure below the median postoperative completeness of the old charts was 60%

while the median preoperative completeness of the DPPS charts was 80%. Postoperative completeness of the old charts had wider variation as compared to DPPS

charts. Furthermore it was found that on average DPPS charts had significantly (Mann Whitney U test: $Z = -8.049$, $p\text{-value} = 0.000$) higher postoperative

completeness as compared to the old charts. This showed that the new DPPS system enhanced postoperative documentation by 20%.

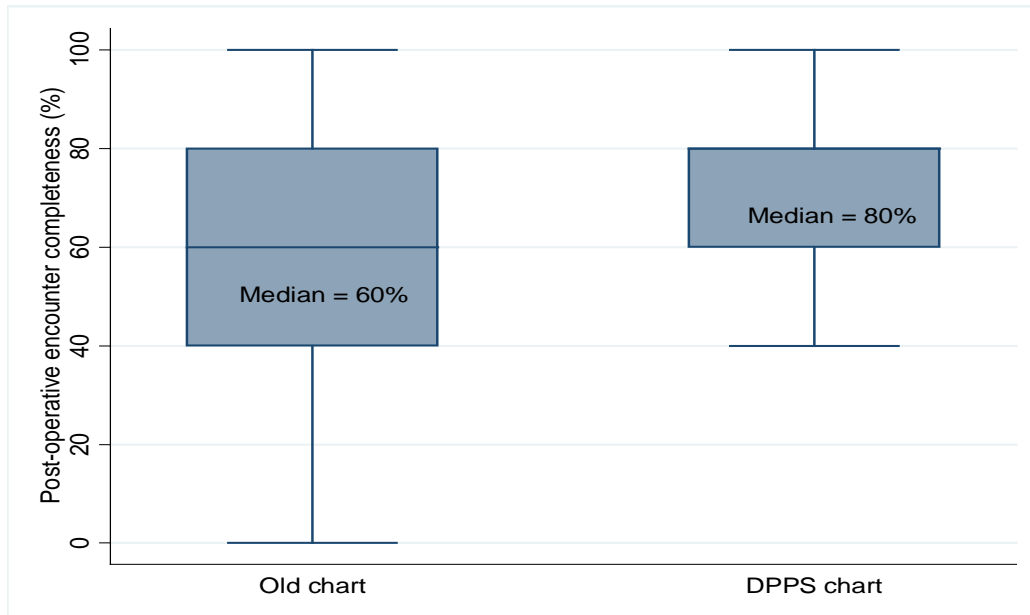


Figure 6: Postoperative Completeness

e) General Completeness

To assess the general completeness scores for preoperative, intraoperative and postoperative completeness were added and converted to percentages. As shown in the figure below the general median completeness of the old charts was 47.5% while the general median completeness of the DPPS charts

was 65%. None of the charts had a completeness of more than 70%. In addition, it was found that on average DPPS charts had significantly (Mann Whitney U test: $Z = -11.07$, $p\text{-value} = 0.000$) higher general completeness as compared to the old charts. This showed that generally the new DPPS system enhanced anaesthetic documentation by 17.5%.

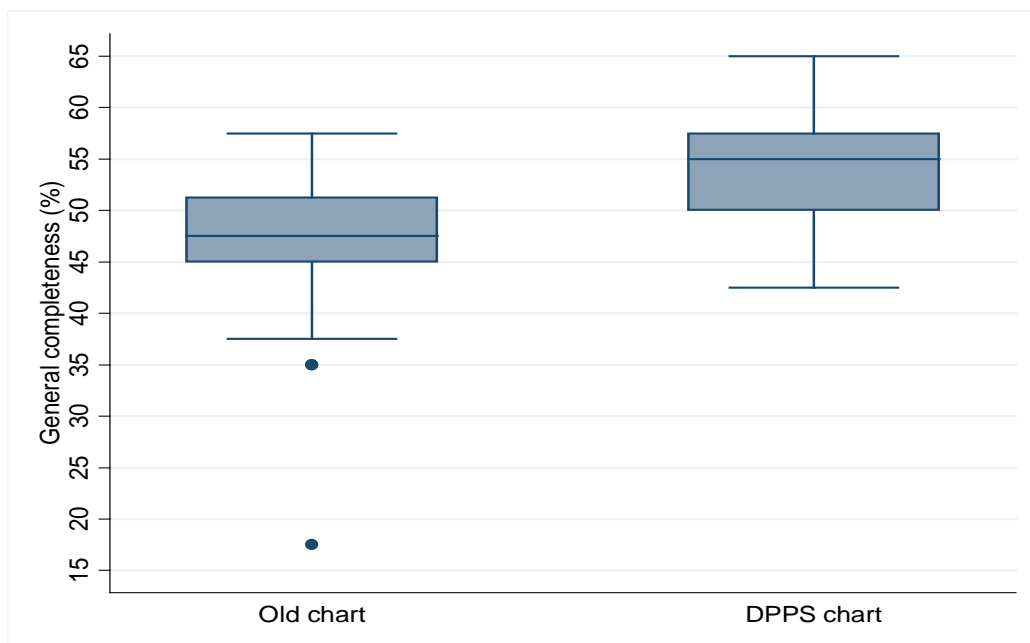


Figure 7: General Completeness

IV. DISCUSSION

Recommendations state anaesthetic documentation should be 100% complete in all aspects.^{4,26} Improved documentation has been associated with well-designed peri-anaesthesia charts, training emphasizing the value of documentation, electronic data capture and departmental monitoring of the quality of record-keeping.^{27, 28} A new obstetric chart was designed with the hope that improved structure would boost the documentation practices. In the early phases of the study, the researcher held a training lecture on best practices in record-keeping using the new chart and DPPS. Although the principal aim was to improve format of the chart to raise documentation standards, the researcher inadvertently taught on the importance of enumerating events. Teaching was done during training on DPPS use. This may explain the generally refined documentation practices during the study.

This study found that prior to the introduction of DPPS, preoperative completion averaged 50% and intraoperative completion was 53% while postoperative completion was 60%. Other studies have demonstrated pre-operative record completion of 26.8%.²³ and a South African study had 78.1% of anaesthetic charts without a pre-operative record.^{22,23} Mato also showed record completion was only 52% across disciplines including orthopedics, obstetrics, ear nose and throat and maxillofacial surgery.² On assessing record keeping during Caesarean section, Varma showed only 6% of charts were completely filled, whilst our initial audit fared at 0%.³⁸ Olateju et al's pre-intervention audit showed 56.12% completeness for obstetric regional anesthesia documentation.^{27,29} Completeness of chart documentation is therefore clearly a major problem, particularly during the pre-operative phase.

After introduction of DPPS, average documentation increased from 47.5% in the old charts to 65% using the new DPPS chart. This indicated that the mean difference between the two documentation styles was 17.5%. The new DPPS documentation had higher effects in postoperative documentation (mean difference 20%) as compared to preoperative documentation (mean difference 10%). The new DPPS however had marginal effects on intra-operative documentation. Therefore, it was concluded that the new DPPS was superior in documenting preoperative and postoperative procedures.

This study supports the hypothesis that anaesthetic documentation in the obstetric population would be superior with the use of the new chart and a DPPS. However, there were emerging problems that may need further evaluation at a later stage such as the data needing further verification and the quality of the pen-hand recognition. During the study form verification and correction was only done on 10 randomly selected

forms. Although the DPPS may be a potential bridge technology, it probably does not fully address the issues surrounding hand-recognition and the additional time required for data verification and cleaning. This will need further validation at a later stage in our unit. Dykes also showed similar potential issues of the DPPS when it was employed in 3 units at varied stages of implementing an electronic medical record.³³

V. RECOMMENDATIONS

To further approach the gold standard 100% documentation, we would recommend periodic departmental education on the importance of enumerating events during the manual-to-digital transition.

VI. LIMITATIONS

The study was conducted at teaching hospitals which may not necessarily depict practices at other hospitals. We assumed that users are equally capable and so individual skill would not affect documentation. Junior members of staff enter the department on a rotational basis. The study was conducted during randomly selected months without taking rotations into consideration.

VII. CONCLUSION

Data capture in the operating room takes many forms.³⁴ we developed an obstetric anaesthetic chart using the DPPS in a low-resource setting. A digital charting tool improved data collection in terms of quantity although the quality was not fully evaluated. The DPPS showed some potential value in a low-resource setting especially with regards to degree of chart completion and facilitation of big data amongst others.

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Declaration

The authors declare that they have no competing interests. Xcalibre is an independent company from which the study DPPS was sought commercially. The company had no involvement or financial interest in the study. All authors cited above had contributions in the conception, study design, data acquisition, analysis and development of this manuscript. The datasets used and analyzed for this study are available upon reasonable request with permission from JREC and the Ministry of Health.

List of Abbreviations

AIMS Anesthesia Information Management System
ASA American Society of Anesthesiologists

CI	Confidence Interval
CS	Caesarean Section
DPPS	Digital Pen and Paper System
FGD	Focus Group Discussion
HCH	Harare Central Hospital
JREC	Joint Research Ethics Committee
PGH	Parirenyatwa General Hospital

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