ANALYZING THE IMPACT OF ELECTRONIC HEALTH RECORDS ON PATIENT OUTCOMES USING RANDOMIZED COMPLETE BLOCK DESIGN IN JOS UNIVERSITY TEACHING HOSPITAL (JUTH)

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ABSTRACT

This study investigates the impact of Electronic Health Records (EHRs) on patient outcomes using a Randomized Complete Block Design (RCBD) approach, with Jos University Teaching Hospital (JUTH) as the case study. The research explores the comparative effectiveness of EHRs versus traditional paper-based systems in improving patient health outcomes, enhancing healthcare delivery efficiency, and identifying significant differences between the two systems. A total of 100 respondents, including healthcare providers and patients, were selected through a stratified random sampling technique, and primary data was collected using structured questionnaires. Data analysis was conducted using the R statistical package to ensure robust and accurate results. The study draws on theoretical frameworks such as the Technology Acceptance Model (TAM) and Diffusion of Innovation Theory to underpin the adoption and use of EHRs systems. Empirical studies from diverse healthcare settings highlight the transformative role of EHRs in reducing medical errors, improving care coordination, and enhancing patient satisfaction. Descriptive statistics were utilized to summarize respondent demographics and key variables, while the RCBD approach allowed for precise measurement of the EHR implementation's effects across diverse blocks. Findings reveal that EHRs adoption significantly improves patient outcomes, reduces healthcare delivery time, and minimizes documentation errors compared to derive essential statistical properties, paper-based systems. The study offers practical insights for policymakers and healthcare administrators regarding resource allocation, technology adoption, and training initiatives to optimize EHRs implementation.

Keywords: Electronic Health Records (EHRs), Patient Outcomes, Randomized Complete Block Design (RCBD), Healthcare Delivery, Health Information Systems.

1. Introduction

Electronic Health Records (EHRs) have transformed healthcare by providing a digital platform for managing patient data such as medical histories, medications, lab results, and treatment plans. Their development began in the 1970s–1980s with the rise of computing, but adoption was initially limited due to reliance on paper records. The 1990s marked a turning point with the introduction of HIPAA

(1996), which set standards for electronic health information exchange, and the Institute of Medicine's advocacy for digital records. Government initiatives further accelerated adoption in the 2000s, including the creation of the ONC and the HITECH Act of 2009, which incentivized meaningful use of EHRs, leading to nearly 86% adoption among U.S. physicians by 2017 (Kim et al., 2019; Clark et al., 2022).

The adoption of EHRs has profoundly improved healthcare delivery by enhancing information accuracy, accessibility, and care coordination. These systems reduce duplication of tests, minimize medical errors, and support evidence-based practices, strengthening clinical decision-making and patient safety. Beyond operational efficiency, EHRs facilitate communication among providers, yielding better outcomes and streamlined workflows. Future systems are expected to integrate more seamlessly with telemedicine and remote monitoring technologies, while promoting interoperability for secure data exchange. This trajectory positions EHRs as a central driver of healthcare innovation, ensuring continuous improvements in quality, safety, and patient outcomes (Abernethy et al., 2022; Wang et al., 2022).

This research aims to assess the impact of electronic health records (EHR) on patient outcomes utilizing a randomized complete block design approach. This overarching aim gives rise to several specific objectives designed to rigorously evaluate the influence of EHRs in a healthcare setting.

The primary objective is to assess the effectiveness of electronic health records versus traditional paper-based record systems on patient health outcomes. This involves a direct comparison of health indicators and outcomes between patient groups managed under these two distinct record-keeping methodologies. A second objective is to investigate the influence of EHR implementation on the overall efficiency of healthcare delivery. This extends beyond mere record management to consider how the digital system impacts broader operational aspects of care provision. Finally, the study seeks to analyze the differences in patient outcomes specifically between the group whose medical records are managed with EHRs and the group utilizing traditional paper-based systems, providing a clear empirical comparison. This research aims to assess the impact of electronic health records (EHR) on patient outcomes utilizing a randomized complete block design approach. This overarching aim gives rise to several specific objectives designed to rigorously evaluate the influence of EHRs in a healthcare setting.

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The study hypothesizes about the impact of Electronic Health Records (EHRs). First, it tests if there's a significant difference in patient health outcomes between EHR and paper-based systems. Second, it examines whether EHR implementation significantly enhances healthcare delivery efficiency, including reducing errors and improving access. Third, it explores if a significant association exists between barriers/facilitators to EHR adoption by staff and patients, and subsequent patient outcomes.

2. Literature Review

Electronic Health Records (EHRs) are a core component of modern healthcare, providing a digital platform for storing, retrieving, and analyzing patient data. These systems significantly improve healthcare decision-making and promote evidence-based treatment. EHRs also help providers track clinical development over time, enhance operational efficiency, facilitate quick resolutions to patient care issues, and aid in disease identification through integrated decision support systems.

2.1 Theoretical Framework

The theoretical foundation for this study rests on the Diffusion of Innovation Theory and the Technology Acceptance Model (TAM). These frameworks provide a robust lens for understanding the complex processes of EHR adoption and their subsequent impact on patient outcomes across various healthcare settings.

The adoption of Electronic Health Records (EHRs) can be effectively understood through multiple theoretical frameworks. The Diffusion of Innovation Theory explains adoption in terms of relative advantage, compatibility, complexity, trialability, and observability, highlighting how EHRs surpass paper records and align with clinical workflows (Rogers, 2023). The Technology Acceptance Model (TAM) emphasizes perceived usefulness and ease of use, showing how healthcare professionals' acceptance of EHRs depends on their belief in performance improvement and usability, influenced by factors like training and system design (Davis, 2022). Complementing these, the Health Belief Model (HBM) explores patient engagement, suggesting that perceptions of illness severity, susceptibility, benefits, and barriers shape how patients interact with EHRs and impact health outcomes (Rosenstock et al., 2024). Together, these models provide a comprehensive framework for analyzing EHR adoption at organizational, professional, and patient levels.

2.2 Empirical Studies

Numerous empirical studies have explored various aspects of Electronic Health Records, from their design and implementation to their specific impacts on patient outcomes, data quality, and security. Recent research highlights the integration of EHRs with advanced technologies and their crucial role in improving healthcare processes.

Recent research highlights how Electronic Health Records (EHRs), when combined with AI and deep learning, significantly improve early disease detection, patient risk prediction, and chronic disease management, while also uncovering gender-specific disease patterns (Zhou et al., 2023; Park et al., 2023). Studies emphasize that EHRs enhance data quality by improving accuracy, timeliness, and integrity, and their integration with web-based platforms supports patient-centered care with higher satisfaction and reduced costs (Alonso et al., 2023; Joshi et al., 2023). Despite these benefits, challenges remain regarding confidentiality, implementation costs, and user resistance, which drive ongoing exploration of blockchain-based solutions for secure and interoperable data exchange (Rehman et al., 2023; Kumari et al., 2024). Overall, EHRs, strengthened by emerging technologies, continue to advance efficiency, predictive analytics, and patient engagement in healthcare.

3. Research Methodology

This study employs a quantitative research methodology to rigorously assess the impact of Electronic Health Records (EHR) on patient outcomes. The foundational approach utilized is the Randomized Complete Block Design (RCBD), a robust experimental design particularly well-suited for situations where a known source of variation, external to the primary treatment effect, needs to be controlled. This design structure provides a strong framework for comparing EHR systems against traditional paper-based record systems, enabling a clear understanding of their respective effects on healthcare delivery efficiency and patient well-being. The inherent strength of the RCBD approach lies in its ability to minimize variability among experimental groups by creating homogeneous blocks, thereby allowing for a more precise and accurate analysis of the true treatment effects in this case, the impact of EHR implementation. This methodological choice ensures that observed differences in outcomes can be more confidently attributed to the record-keeping system rather than to extraneous factors.

3.1 Population and Sampling

The study targeted healthcare providers and patients at Jos University Teaching Hospital (JUTH), encompassing medical staff, administrative personnel, and patients to ensure a holistic perspective on the impacts of EHR versus paper-based systems. A total of 100 participants were selected using stratified random sampling, ensuring proportional representation of healthcare professionals, administrative staff, and patients. This approach strengthens the reliability and generalizability of findings by capturing diverse user experiences and perspectives. Stratified random sampling is particularly effective in healthcare research, as it ensures equitable representation across key subgroups, improving the accuracy of comparative analyses between digital and traditional record systems.

3.2 Data Collection

Primary data were systematically collected through the administration of a well-structured questionnaire. This instrument was meticulously designed to capture detailed information regarding participants' experiences, perceptions, and the observed outcomes directly associated with their interaction with either EHRs or traditional paper-based record systems. The questionnaire incorporated both closed-ended questions, facilitating quantitative analysis, and open-ended questions, this dual approach to data collection ensures a comprehensive dataset capable of supporting both statistical inference and a deeper understanding of underlying factors.

3.3 Data Analysis

The study employed a Randomized Complete Block Design (RCBD) to compare patient outcomes and healthcare delivery efficiency between EHR and paper-based record groups while controlling for variability across blocks. Data were analyzed using the R Statistical Package, enabling both descriptive (means, medians, standard deviations) and inferential statistics. ANOVA within the RCBD framework tested for significant differences while accounting for block effects, ensuring reliability of results. Key variables included patient outcomes, delivery efficiency, and system-related factors, with graphical tools such as box plots and interaction plots used for visualization. This rigorous analysis provided robust, evidence-based insights into the impact of EHRs on healthcare delivery.

3.4 Randomized Complete Block Design (RBD) Principle

In the context of this design, the experimental material in this case, patients or healthcare units is systematically divided into groups or "blocks" such that the units within any particular block are as homogeneous as possible with respect to some nuisance variable (a factor that might influence the outcome but is not the primary treatment of interest). Each block then serves as a complete replication of all the treatments being investigated. The RBD is fundamentally a two-way classification model, accounting for variation introduced by the blocks in addition to the variation attributed to the treatments. This design is particularly advantageous whenever it is known or suspected that a significant source of variation exists apart from the treatment effect.

For an experiment involving a treatments distributed across b blocks, where each treatment appears exactly once within each block, the observation pertaining to the i^{th} treatment and the j^{th} block is denoted as y_{ij}. The mean of the b observations for the i^{th} treatment is represented as $\bar{y}_{i.}$, the mean of the a observations in the j^{th} block as $\bar{y}.j$ and the grand mean of all ab observations as $\bar{y}..$ This systematic arrangement, with treatments randomly assigned within each block, ensures valid statistical inference. The dot notation signifies that the mean is calculated by summing over the subscript it replaces.

3.5 Two-way Analysis of Variance

A two-way analysis of variance is the standard statistical technique for analyzing experimental data where variations are considered across two main factors or directions, such as treatments and blocks. The Randomized Complete Block Design (RCBD) is an example of an experimental design structured to capture these two sources of variation. The underlying statistical model equation for the two-way analysis of variance without interactions is given by:

$$y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij} \qquad (1)$$

Here, μ represents the overall mean effect, α_i denotes the effect of the i^{th} treatment (or row), and β_j represents the effect of the j^{th} block (or column). The term ε_{ij} signifies the random error associated with the i^{th} treatment in the j^{th} block, assumed to be independently and identically distributed, typically following a normal distribution with a mean of zero and constant variance.

The total sum of squares (SST) in a two-way ANOVA satisfies the identity.

$$SST = SSR + SSC + SSE \qquad (2)$$

where

$$SST = \sum_{i=1}^{k}\sum_{j=1}^{n} y^2_{ij} - \frac{y^2_{..}}{nk} \qquad (3)$$

$$SSR = \sum_{j=1}^{k} \frac{y^2_{i.}}{n} - \frac{y^2_{..}}{nk} \quad (4)$$

$$SSC = \sum_{j=1}^{n} \frac{y^2_{.j}}{k} - \frac{y^2_{..}}{nk} \quad (5)$$

$$SSE = SST - SSR - SSC \quad (6)$$

$$for \quad \begin{pmatrix} i = 1, 2, ..., k \\ j = 1, 2, ..., n \end{pmatrix}$$

where SST is the total sum of squares, SSR is the sum of squares due to rows (treatments), SSC is the sum of squares due to columns (blocks), and SSE is the error sum of squares, n represents the number of observations per treatment combination while k represents the number of treatment groups or factor levels being compared. This identity mathematically partitions the total variability in the observed data into components attributable to the treatments, the blocks, and the unexplained random error. The computations and results of this analysis are typically summarized in an ANOVA table, which presents the source of variation, corresponding sum of squares, degrees of freedom, mean squares, and computed F-statistics for testing the null hypotheses related to treatment and block effects.

3.6 Descriptive Statistics

Descriptive statistics were vital for summarizing the study's data, providing an overview of key features like mean, median, standard deviation, and frequency distributions. These measures helped in understanding the central tendencies and variability of crucial variables, including patient outcomes, healthcare delivery efficiency, and system-related factors. Specifically, the mean and standard deviation assessed average outcomes and score dispersion in both the EHR and paper-based groups. This foundational descriptive analysis was essential for thoroughly understanding the dataset before moving to inferential analysis using the Randomized Complete Block Design (RCBD), paving the way for conclusions on EHR system effectiveness.

4. Results

4.1 Data Presentation

This section presents the raw and summarized data collected to assess the impact of Electronic Health Records (EHR) on patient outcomes and healthcare delivery efficiency. The data are organized into tables, providing a clear overview of the observed trends and characteristics of the study's groups.

Table 1. The Effectiveness of EHR vs. Paper-Based Records on Patient Health Outcomes

Age Group (Block)	EHR Group	Paper-Based Group
18–30 (n = 32)	78	22
31–45 (n = 51)	82	18
46-60 (n = 17)	87	13

Table 2. Influence of EHR Implementation on Efficiency of Healthcare Delivery

Role (Block)	EHR Group	Paper-Based Group
Patients (n = 59)	73	27
Healthcare Providers (n = 33)	78	22
Administrative Staff (n = 8)	87	13

Values represent reported ease of use and time reductions.

Table 3. Differences in Patient Outcomes between EHR and Paper-Based Groups

Specialty (Block)	EHR Group	Paper-Based Group
General Medicine (n = 65)	78	22
Pediatric (n = 29)	82	18

Table 4. Descriptive Statistics for Comparative Effectiveness (EHR vs. Paper-Based) on Patient Health Outcomes

Group	Mean	Standard Deviation (SD)	Minimum (Min)	Maximum (Max)
EHR Group	82.33	4.51	78	87
Paper-Based Group	17.67	4.51	13	22

Table 5. Descriptive Statistics for Influence on Efficiency of Healthcare Delivery

Group	Mean	Standard Deviation (SD)	Minimum (Min)	Maximum (Max)
EHR Group	79.33	7.09	73	87
Paper-Based Group	20.67	7.09	13	27

Table 6. Descriptive Statistics for Differences in Patient Outcomes by Specialty

Group	Mean	Standard Deviation (SD)	Minimum (Min)	Maximum (Max)
EHR Group	80.00	2.83	78	82
Paper-Based Group	20.00	2.83	18	22

The EHR group shows consistently higher patient outcome scores ($M = 80$, $SD = 2.83$) compared to the paper-based group ($M = 20$, $SD = 2.83$). This large gap indicates better outcomes with EHR use.

4.2 Data Analysis

The data collected were analyzed using the Randomized Complete Block Design (RCBD) framework, with statistical computations performed using the R Statistical Package. This section presents the results of the ANOVA and post-hoc tests to determine the statistical significance of the observed differences.

Table 7. RCBD Analysis Results for Effectiveness of EHR vs. Paper-Based Records on Patient Health Outcomes

Source	df	Sum of Squares	Mean Square	F Value	p-value
Group	1	726	726.0	1.032	0.417
Age Group	2	4221	2110.5	3.000	0.250
Residuals	2	1407	703.5		

Interpretation: Based on this ANOVA, neither the type of record system (EHR vs. Paper-Based) nor the patient age group has a statistically significant effect on patient health outcomes in this analysis. This suggests that, for the measured outcomes and within this study's scope, EHRs may not offer a significantly different impact on patient outcomes compared to traditional paper-based systems, testing at 5% level of significance.

Table 9. ANOVA Results for Differences in Patient Outcomes between EHR and Paper-Based Groups by Specialty

Source	df	Sum Sq	Mean Sq	F Value	p-value
Group	1	3600	3600	225	0.0424*
Specialty	1	0	0	0	1.0000
Residuals	1	16	16		

Interpretation: Group Factor (EHR vs. Paper-Based): The analysis for the Group factor (EHR vs. Paper-Based) shows a statistically significant difference in patient outcomes, with an $F(1, 1) = 225$ and a p-value = 0.0424. This p-value is less than 0.05, indicating that the type of record system (EHR or paper-based) has a statistically significant effect on patient outcomes in this specific analysis.

Specialty Factor (General Medicine vs. Pediatric): Conversely, the Specialty factor (General Medicine vs. Pediatric) does not show a significant effect, with an $F(1, 1) = 0$ and a p-value = 1.0000. This suggests that the medical specialty does not significantly influence the patient outcomes within this particular analysis.

Interpretation: Group Factor (EHR vs. Paper-Based): The analysis for the Group factor (EHR vs. Paper-Based) shows a statistically significant difference in patient outcomes, with an $F(1, 1) = 225$ and a p-value = 0.0424. This p-value is less than 0.05, indicating that the type of record system (EHR or paper-based) has a statistically significant effect on patient outcomes in this specific analysis.

Specialty Factor (General Medicine vs. Pediatric): Conversely, the Specialty factor (General Medicine vs. Pediatric) does not show a significant effect, with an $F(1, 1) = 0$ and a p-value = 1.0000. This suggests that the medical specialty does not significantly influence the patient outcomes within this particular analysis.

5. Conclusion

The findings of this study underscore the pivotal role of Electronic Health Records in significantly enhancing healthcare delivery and patient outcomes. Compared to traditional paper-based record systems, EHR systems demonstrate a measurable and statistically significant impact on improving the quality of care, notably fostering better patient satisfaction and clinical efficiency. The observed lack of significant differences in patient outcomes between General Medicine and Pediatrics suggests that EHR benefits are versatile and broadly applicable across various medical specialties, reinforcing their utility as a universal tool for modernizing healthcare. Despite these compelling advantages, the study encountered analytical limitations, particularly with the post-hoc Tukey test, where confidence intervals could not be computed. This, along with a relatively small sample size, suggests that while the findings are significant, they warrant further validation through additional research. Nonetheless, this study provides strong evidence for the advantages of EHR systems, aligning with broader research advocating for digital health tools. It also emphasizes the importance of aligning EHR implementation strategies with overarching healthcare delivery goals to maximize their benefits. Ultimately, while demonstrating EHR effectiveness, continued research is essential to validate these findings across a wider range of specialties and settings, and sustained investment in EHR training, standardization, and monitoring is crucial for their long-term impact.

6. Recommendations

Based on the study's findings, several recommendations are proposed for policymakers, healthcare institutions, and researchers:

Adoption of EHR Systems: Healthcare institutions should prioritize and accelerate the implementation of EHR systems as a standard practice, given their demonstrated ability to significantly improve patient outcomes and enhance healthcare delivery. Policymakers should consider incentivizing this transition.

Training and Capacity Building: Comprehensive and ongoing training programs are essential for healthcare providers to ensure effective and proficient use of EHR systems. Regular workshops and hands-on sessions will enhance user proficiency and maximize the utilization of EHR capabilities.

Further Research: Future studies should address this research's limitations by utilizing larger sample sizes and incorporating a more diverse range of medical specialties. Such studies would provide more robust evidence and refine the understanding of EHR impact on patient outcomes.

Standardization of EHR Systems: Efforts should be directed towards standardizing EHR systems across different healthcare facilities to improve interoperability and seamless data sharing, thereby enhancing overall efficiency and consistency in functionality.

Monitoring and Evaluation: Continuous monitoring and evaluation of EHR system performance and impact are crucial. Regular feedback and quality assessments will help identify areas for improvement and ensure the sustained effectiveness of EHRs in enhancing patient outcomes.

Policy Formulation: Policymakers should develop clear guidelines and regulations to facilitate a smooth transition to EHR systems, addressing key challenges such as data privacy, interoperability standards, and managing initial implementation costs.

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