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ORIGINAL RESEARCH

Impact of Big Data Analytics on Emergency Department Efficiency in Saudi Ministry of Health Hospitals: A Retrospective Data Analysis

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Background: The integration of big data analytics in healthcare has become essential for enhancing operational performance, particularly within Emergency Departments (EDs), where efficiency improvements can significantly impact patient satisfaction and resource utilization.

Aim: This study examines the impact of big data analytics on ED performance metrics within Saudi Arabia's Ministry of Health (MOH) hospitals, with a focus on key performance indicators (KPIs) and the effectiveness of the Ada'a Health Program in optimizing ED operations.

Methods: A retrospective observational study was conducted across 10 hospitals in five regions of Saudi Arabia. Data from 228,857 patient records were analyzed, alongside survey responses from 223 ED personnel. Statistical analyses, including paired t-tests, Pearson's correlation, and multiple regression models, were used to evaluate improvements in KPIs and assess the program's impact.

Results: Significant improvements in all KPIs were observed following the implementation of the Adaa Health Program. Door-to-Doctor Time decreased from 28:26 to 25:13, Doctor-to-Decision Time from 1:18:22 to 1:03:50, Decision-to-Disposition Time from 36:37 to 20:13, and Door-to-Disposition Time from 2:22:02 to 1:48:44. Pearson's correlation analysis indicated a strong relationship between Decision-to-Disposition Time and Doctor-to-Decision Time ($r = 0.594$), emphasizing the role of clinical decision-making in patient flow. Regression analysis further confirmed the program's significant association with reduced wait times ($p < 0.001$).

Conclusion: This study highlights the transformative impact of big data-driven decision-making in optimizing ED efficiency. The Ada'a Health Program has significantly improved patient flow, reduced congestion, and enhanced operational performance in Saudi MOH hospitals. These findings underscore the need for continued investment in big data analytics, updated predictive modeling, and workflow automation to sustain and further enhance ED efficiency. Future research should explore scalability across diverse healthcare settings and the long-term sustainability of such interventions.

Plain Language Summary: This study examines how big data analytics can enhance the efficiency of Emergency Departments (EDs) in hospitals under Saudi Arabia's Ministry of Health (MOH). By analyzing data from over 228,000 patient records across 10 hospitals, we assessed the impact of the Ada'a Health Program, a data-driven initiative designed to improve hospital performance. Specifically, we evaluated Key Performance Indicators (KPIs), including the time it takes for patients to see a doctor, receive a treatment decision, and complete their ED visit.

The findings revealed significant reductions in patient wait times from 2019 to 2021. For example, the time from arrival to seeing a doctor decreased from 28 minutes to 25 minutes, while the total time spent in the ED was reduced by over 30 minutes, demonstrating more efficient patient flow. These improvements highlight how real-time data monitoring and workflow optimization have enhanced resource management, service quality, and patient satisfaction in emergency care settings.

This study underscores the transformative power of big data in healthcare, showing how data-driven decision-making can streamline hospital operations, reduce congestion, and improve patient experiences. The results emphasize the importance of continued investment in big data analytics to sustain and expand these benefits across healthcare systems.

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Introduction

Healthcare is a multifaceted system that prevents, diagnoses, and treats human health disorders. Health personnel (nurses or physicians), health facilities (hospitals and clinics that provide medications and treatment or diagnosis technology), and a financial institution that supports them all make up the healthcare system. The health professions provide advice, acute care, medical investigation or therapy, surgical operations, and rare diagnostics (quaternary care). At all levels, health practitioners are responsible for clinical and medical data such as laboratory and imaging examinations, patient medical history (prescriptions and diagnosis), and other personal or private medical data.[1]

Electronic health systems are expected to increase interest in big data from electronic medical records as technology advances. Healthcare systems must alter to enable the big-data revolution. As more information becomes public, healthcare stakeholders must protect patient privacy and secure information-releasing businesses. Big data analytics, healthcare efficiency, waste reduction, and clinical process streamlining are difficult to implement. Healthcare leaders require data-driven decisions to improve service quality.[2,3]

Big data analysis, data collection, and data quality underpin these processes.[4] The Saudi Ministry of Health is investing heavily in performance improvement projects at hundreds of healthcare facilities to boost productivity, efficiency, quality, and patient satisfaction. Healthcare companies, especially hospitals, need to monitor clinical performance before managing it. These activities require regular, ongoing data collection, analysis, and validation. Clinical and non-clinical leaders could use these methods to make data-driven decisions and discover pain points and root causes for improvement.[5,6]

Saudi Arabia has a new ER. Opportunities and challenges in emergency department development are crucial to understanding its current state, history, and future. The public health system in Saudi Arabia provides 80% of healthcare through at least 3,000 basic healthcare institutions.[7] The Saudi Ministry of Health (MoH) runs 60% of basic healthcare institutions and hospitals.[8] Big data management and analysis must be understood by healthcare officials to reduce waste and improve the system. Digital solutions, big data analytics, and management are vital for these efforts. Nonetheless, the Ministry of the Interior (MoI), Ministry of Education (MoE), Royal Commission for Jubail and Yanbu, Ministry of National Guard (MNG), and Ministry of Defense (MoD) supply the remaining 20% of healthcare services in the country.[9] These agencies provide healthcare to predefined recipients, including their employees and families. Saudi healthcare is 20% private. Yet, visitors and foreigners have access to emergency department healthcare.

To enhance hospital efficiency and optimize emergency department operations, the Ada'a Health Program was introduced in 2016 as part of the National Transformation Program (NTP). The initiative serves as a key enabler in improving healthcare performance by integrating data-driven decision-making, Lean Thinking methodologies, and digital reporting systems. The program currently operates in over 150 hospitals and 700 Primary Healthcare Centers across Saudi Arabia, covering seven high-priority functional areas: Emergency Departments (ED), Outpatient Clinics (OPD), Inpatient Services (IP), Operating Rooms (OR), Critical Care, Laboratories, and Radiology. Through the program, more than 500 targeted performance improvement initiatives have been implemented, significantly enhancing key performance indicators (KPIs), patient access, and hospital productivity. Additionally, 42 standardized KPIs are continuously measured to monitor operational performance, identify inefficiencies, and streamline hospital workflows. By leveraging big data analytics, the Ada'a Health Program has fostered a cultural shift towards continuous performance improvement, enabling healthcare leaders to optimize resource utilization, improve clinical outcomes, and enhance patient satisfaction.[10,11]

Building on the significance of big data in enhancing healthcare operations, this study aims to delve into the specific impact of big data analytics on the operational performance of Emergency Departments (ED) within the Ministry of Health (MOH) hospitals in Saudi Arabia. By focusing on performance improvement projects across 10 selected hospitals, this research seeks to uncover how big data initiatives influence efficiency, productivity, and overall quality within these critical care settings. Additionally, the study examines the role of the Ada'a Health Program in fostering operational

improvements by enhancing hospital teams' skills and capabilities, ultimately balancing productivity and streamlining workflows. Through these objectives, the research will provide valuable insights into how data-driven strategies can transform emergency healthcare services, optimizing outcomes for patients and healthcare providers alike.

Materials and Methods

Research Design

This study investigates the impact of big data analytics on emergency department (ED) performance within the Ministry of Health (MoH) hospitals in Saudi Arabia. The study employed a retrospective observational design, analyzing both primary data (survey responses from ED personnel) and secondary data (patient records extracted from the Ada'a Health Program Database) to assess changes in key performance indicators (KPIs) over time.

The study was conducted in 10 randomly selected hospitals across five major regions in Saudi Arabia, ensuring geographic representation. Data from September 2019 to January 2022 were included, covering approximately 200,000 patient cases. The primary objective was to evaluate whether the implementation of big data analytics and the Ada'a Health Program resulted in improvements in ED operational efficiency, particularly in patient flow and care timelines.

Study Setting and Hospital Selection

Hospitals were selected based on the following criteria:

- Geographic distribution: Ensuring representation from all five Saudi regions (Central, East, West, North, and South).
- Operational capacity: Inclusion of both high-volume and mid-sized hospitals to reflect diverse hospital settings.
- Big data system integration: Hospitals that fully integrated the Ada'a Health Program within their operational framework.

The 10 selected hospitals included:

- Asir Central Hospital, Asir (South Region)
- King Abdullah Hospital, Bisha (South Region)
- Al Noor Hospital, Makkah (West Region)
- King Abdullah Medical Complex, Jeddah (West Region)
- King Salman Hospital, Riyadh (Central Region)
- Buraydah Central Hospital, Buraydah (Central Region)
- Prince Muteb Hospital, Al Jouf (North Region)
- King Fahad Hospital, Tabuk (North Region)
- MCH Al Ahssa (East Region)
- MCH Dammam (East Region)

These hospitals were chosen due to their high emergency admission rates, with each admitting an average of 20,000–35,000 emergency cases per month.

Data Collection

Primary and Secondary Data

Primary Data – Survey of ED Personnel

A structured questionnaire was administered to 223 emergency department healthcare workers across the selected hospitals.

- **Inclusion criteria**: Physicians (consultants, specialists, and residents), nurses, and ED administrative staff directly involved in patient care and workflow management.
- **Survey Content**:
  - Demographics (age, gender, professional role, years of experience).
  - Familiarity with big data and digital systems in ED operations.
  - Perceived impact of big data on ED efficiency, workflow, and patient care.
  - Challenges and barriers in implementing big data-driven improvements.

Participants were selected using **convenience sampling**, ensuring diverse representation within ED teams.

Secondary Data – Ada'a Health Program Database

Secondary data were extracted from the Ada'a Health Program Database, which systematically tracks ED performance metrics. All patient data were de-identified before analysis, ensuring compliance with ethical regulations.

The study analyzed the following four key performance indicators (KPIs):

1. **Door-to-Doctor Time**: Time from patient arrival to first medical consultation.
2. **Doctor-to-Decision Time**: Time from first consultation to clinical decision (admission, discharge, or further evaluation).
3. **Decision-to-Disposition Time**: Time from clinical decision to final patient disposition.
4. **Door-to-Disposition Time**: Total time from ED arrival to final patient outcome.

Data Recording Process

- All KPIs were automatically recorded through the hospital's electronic health records (EHR) system and aggregated in the Ada'a Health Program Database.
- ED performance officers validated the data for accuracy before submission.
- No patient-reported data were included; all variables were system-generated and hospital-validated.

Data Cleaning & Preprocessing

Before statistical analysis, all datasets were cleaned and validated:

- Missing data entries were flagged and reviewed.
- Data consistency was ensured by cross-referencing hospital-reported KPIs with Ada'a Health Program records.
- Outliers (eg extreme waiting times) were assessed and adjusted if necessary.

Statistical Analysis

The statistical analysis was conducted using SPSS version 27. Descriptive statistics, including means, standard deviations, and frequency distributions, were used to summarize patient demographics and key ED performance indicators. A paired *t*-test was applied to compare key performance metrics before and after the implementation of the Ada'a Health Program. Additionally, a chi-square test was used to assess differences in patient characteristics, ensuring comparability between the pre- and post-intervention groups. To further evaluate the impact of big data analytics while controlling for potential confounders, a multiple linear regression analysis was performed, assessing changes in key ED efficiency metrics. The results demonstrated significant improvements in wait times and operational efficiency, highlighting the effectiveness of data-driven decision-making in enhancing emergency department performance.

Ethical Approval

This study received ethical approval from the Directorate of Health Affairs – Taif, Ministry of Health, Saudi Arabia (Approval no. HAP-02-T-067). While this committee does not match the authors' institutional affiliations, it is the

designated ethics committee responsible for overseeing studies conducted in MoH facilities, including the hospitals involved in this research. This aligns with Saudi Arabia's national guidelines for ethical oversight within MoH hospitals.

Results

Table 1 shows a comparative analysis of key performance indicators (KPIs) in emergency departments before and after the implementation of the Ada'a Health Program. The data includes median and interquartile ranges (IQRs) for four main KPIs: Door-to-Doctor Time, Doctor-to-Decision Time, Decision-to-Disposition Time, and Door-to-Disposition Time. The results demonstrate a significant reduction in waiting times across all measured indicators. Notably, Door-to-Doctor Time decreased from 28 minutes and 26 seconds to 25 minutes and 13 seconds, reflecting quicker initial consultations. Similarly, Doctor-to-Decision Time was reduced from 1 hour and 18 minutes to 1 hour and 3 minutes, suggesting enhanced efficiency in clinical decision-making. The most significant improvement was observed in Decision-to-Disposition Time, which dropped from 36 minutes and 37 seconds to 20 minutes and 13 seconds, indicating a faster transition from decision-making to patient disposition. Lastly, Door-to-Disposition Time was significantly reduced, from 2 hours and 22 minutes to 1 hour and 48 minutes, emphasizing improved overall ED efficiency. These reductions suggest that workflow enhancements and data-driven decision-making introduced by the Ada'a Health Program contributed to improved patient throughput and reduced congestion in emergency departments.

Table 2 shows the distribution of patients across different regions in Saudi Arabia, providing insight into the geographical representation of the study sample. The dataset includes a total of 228,857 patients across five major regions: Central, East, North, South, and West. The highest patient volume was recorded in the Western region (25.1%), followed by the Northern region (24.0%), indicating high emergency department utilization in these areas. The Southern and Eastern regions contributed 18.6% and 17.8%, respectively, while the Central region accounted for the lowest percentage (14.4%) of patients in the study. The regional variation in patient volume highlights the differences in healthcare demand and suggests that hospitals in higher-volume regions may face greater strain on emergency department resources. This distribution helps contextualize the impact of big data-driven interventions across diverse healthcare settings in Saudi Arabia.

Table 3 presents the distribution of patients across ten major hospitals included in the study, highlighting variations in emergency department (ED) utilization across different healthcare facilities. Al Noor Hospital (West) accounted for the

Table 1 Changes in Emergency Department KPIs Before and After the Ada'a Health Program

KPI	2019 (Pre-Implementation) Median (IQR)	2021 (Post-Implementation) Median (IQR)	p-value
Door-to-Doctor (minutes)	28 (20–40)	25 (18–36)	<0.001
Doctor-to-Decision (minutes)	78 (65–98)	63 (50–80)	<0.001
Decision-to-Disposition (minutes)	36 (24–55)	20 (14–35)	<0.001
Door-to-Disposition (minutes)	142 (110–180)	108 (85–145)	<0.001

Table 2 Sample Distribution by Region

Region	Number of Patients	Percentage (%)
West (Makkah & Jeddah)	57,532	25.1%
North (Al Jouf & Tabuk)	54,880	24.0%
South (Asir & Bisha)	42,609	18.6%
East (AlAhssa & Dammam)	40,789	17.8%
Central (Riyadh & Buraydah)	33,047	14.4%
Total	228,857	100.0%

Table 3 Sample Distribution by Hospital

		Number of Patients	% From Sample	Cumulative Percent
Valid	Asir Central Hospital, South	19641	8.6	8.6
	Al Noor Hospital, West	39289	17.2	25.7
	Buraydah Central Hospital, Central	14659	6.4	32.2
	King Abdullah Hospital, South	22968	10.0	42.2
	King Abdullah Medical Complex, West	18243	8.0	50.2
	King Fahad Hospital, North	29603	12.9	63.1
	King Salman Hospital, Central	18388	8.0	71.1
	MCH AlAhssa, East	18106	7.9	79.0
	MCH Dammam, East	22683	9.9	89.0
	Prince Muteb Hospital, North	25277	11.0	100.0
	Total	**228857**	**100.0**	

highest patient volume (17.2%), followed by King Fahad Hospital (North) (12.9%) and Prince Muteb Hospital (North) (11.0%), indicating a substantial demand for emergency services in these locations. Conversely, Buraydah Central Hospital (Central) contributed the lowest percentage of patients (6.4%), suggesting lower ED patient flow or different referral patterns.

The variability in patient distribution across hospitals likely reflects differences in hospital capacity, geographic accessibility, and regional healthcare demand. Notably, the combined patient share of hospitals in the South (Asir Central Hospital & King Abdullah Hospital) and West (Al Noor Hospital & King Abdullah Medical Complex) regions accounted for a significant portion of the sample, emphasizing the burden placed on ED resources in these areas. Additionally, hospitals in the East region (MCH AlAhssa & MCH Dammam) collectively contributed 17.8% of the sample, suggesting that ED utilization in this region is also substantial.

Table 4 presents the distribution of patient discharge outcomes in emergency departments, providing insights into post-treatment patient flow and hospital bed occupancy trends. The majority of patients (80.2%) were discharged home, indicating that most ED visits did not require hospitalization and were likely managed with outpatient care.

Table 4 Discharge Type Distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Another Health Facility	1870	0.88	0.8	0.8
	Discharge Against Medical Advice -DAMA	5395	2.4	2.4	3.2
	Deceased	419	0.2	0.2	3.4
	Home	183461	80.2	80.2	83.5
	Intensive Care Unit –ICU	3163	1.4	1.4	84.9
	Leave Against Medical Advice- LAMA	3985	1.7	1.7	86.7
	Newborn Intensive Care Unit –NICU	15	0	0	86.7
	Pediatric Intensive Care Unit- PICU	35	0	0	86.7
	Ward	30484	13.3	13.3	100.0
	Total	**228827**	**100.0**	**100.0**	

Hospital admissions to inpatient wards accounted for 13.3% of total discharges, while a smaller proportion (1.4%) of cases required intensive care unit (ICU) transfer, reflecting the severity of conditions requiring critical interventions. Additionally, a small percentage of newborns and pediatric cases were admitted to neonatal (NICU) and pediatric (PICU) intensive care units, representing highly specialized emergency cases.

Notably, 1.7% of patients left against medical advice (LAMA), and 2.4% were discharged against medical advice (DAMA). These figures highlight challenges in patient compliance and continuity of care, which may require intervention strategies such as patient education and enhanced discharge counseling to improve adherence to medical recommendations.

A minor fraction (0.2%) of cases resulted in patient death, underscoring the critical nature of some ED visits and the importance of rapid triage and treatment protocols to manage life-threatening conditions.

Table 5 shows the results of an independent samples *t*-test comparing emergency department wait times before and after the Ada'a Health Program. The statistical analysis confirms significant reductions ($p < 0.001$) in all measured KPIs, with Door-to-Disposition Time showing the largest mean reduction (33 minutes and 18 seconds). The Levene's Test for Equality of Variances indicates statistically significant variance differences, requiring further analysis under both equal and unequal variance assumptions. Under equal variances assumed, the *t*-test yielded a value of $t = 29.549$, $df = 58135$, $p < 0.001$, confirming that the reduction in ED wait times was not due to chance. These results validate the positive impact of the Ada'a Health Program in optimizing ED operations and improving patient flow efficiency.

Table 6 presents the distribution of Canadian Triage and Acuity Scale (CTAS) levels among emergency department (ED) patients, categorizing them based on the urgency of their medical condition. The majority of patients (61.6%) were classified as Level 3 (Urgent), indicating that they required medical attention but were not in immediate life-threatening conditions. Level 4 (Less Urgent) patients accounted for 28.3%, while Level 5 (Non-Urgent) made up 6.1%, highlighting that a significant portion of ED visits were for non-critical cases. Conversely, Level 2 (Emergent) cases, requiring rapid intervention, comprised 3.3%, and the most critical Level 1 (Resuscitation) cases represented only 0.7% of the total patient sample.

Table 5 Canadian Triage and Acuity Scale (CTAS) Levels

	Frequency	Percent	Cumulative Percent
1	1576	0.7	0.7
2	7536	3.3	4.0
3	140,917	61.6	65.6
4	64,868	28.3	93.9
5	13,952	6.1	100.0
Total	**228857**	**100.0**	

Table 6 *t*-Test for ED Performance Improvement

KPI	t-Value	df	p-value
Door-to-Doctor Time	10.715	58,135	<0.001
Doctor-to-Decision Time	19.141	58,135	<0.001
Decision-to-Disposition Time	22.774	58,135	<0.001
Door-to-Disposition Time	29.549	58,135	<0.001

These findings suggest that the majority of ED visits were for urgent but not immediately life-threatening conditions, potentially contributing to ED overcrowding and resource strain. The relatively high percentage of less urgent and non-urgent cases indicates a need for improved triage efficiency and patient redirection strategies, such as enhancing primary healthcare accessibility to manage lower-acuity cases outside the ED. Understanding this distribution allows hospital administrators to optimize resource allocation, prioritize critical patients, and improve overall ED workflow efficiency.

Table 6: Pearson's Correlation Between KPIs

Table 6 shows the Pearson correlation coefficients between Key Performance Indicators (KPIs) to examine relationships among different wait-time metrics. A strong positive correlation ($r = 0.594$) was observed between Decision-to-Disposition Time and Doctor-to-Decision Time, suggesting that delays in clinical decision-making contribute significantly to prolonged patient stays. In contrast, Door-to-Doctor Time showed weak negative correlations (−0.120 and −0.037) with other KPIs, indicating that early consultation times do not strongly impact the total ED stay duration. These findings emphasize the importance of streamlining decision-making processes to improve overall patient throughput, rather than focusing solely on reducing the time to initial consultation.

Table 7 shows the results of a multiple linear regression analysis, evaluating the impact of the Ada'a Health Program on emergency department efficiency while controlling for potential confounders. The analysis indicates that program implementation was significantly associated with a reduction in overall wait times, particularly Door-to-Disposition Time ($\beta = -18.35$, $p < 0.001$). Additional predictors, such as hospital type (central vs peripheral) and patient volume, were also considered to assess variability across different hospital settings. These findings confirm that the implementation of big data-driven strategies contributed to measurable operational improvements in EDs across Saudi Arabia.

Table 8 lists out the Key performance indicators (KPIs) affecting the functioning of the ED. The negative coefficients (β) on all time-related metrics indicate that a decrease in such intervals improves ED performance. Clearly, Doctor-to-Decision Time ($\beta = -10.45$, $p < 0.001$) and Door-to-Disposition Time ($\beta = -18.35$, $p < 0.001$) exert the greatest influence on performance; reducing the time taken for clinical decisions and patient flow markedly improves the efficiency of EDs. For all the KPIs evaluated, the statistically significant p-values ($p < 0.05$) across all KPIs reinforce the robustness of these findings, emphasizing the importance of streamlining patient flow processes to optimize ED outcomes.

Table 7 Pearson's Correlation Matrix

KPI	Decision-to-Disposition	Doctor-to-Decision	Door-to-Doctor
Decision-to-Disposition	1.00	0.594	−0.120
Doctor-to-Decision	0.594	1.00	−0.037
Door-to-Doctor	−0.120	−0.037	1.00

Table 8 Regression Analysis of ED Performance

KPI	Coefficient (β)	p-value
Door-to-Doctor Time	−3.12	0.002
Doctor-to-Decision Time	−10.45	<0.001
Decision-to-Disposition Time	−5.88	<0.001
Door-to-Disposition Time	−18.35	<0.001

Discussion

In recent years, the number of visits to emergency departments (EDs) in Saudi Arabia has increased significantly, leading to prolonged patient wait times and overcrowding. The findings of this study confirm that delays in ED processes contribute to extended patient stays, reinforcing the need for strategic interventions to optimize workflow efficiency. By leveraging big data analytics, healthcare administrators can identify bottlenecks, streamline patient flow, and enhance overall ED operational performance.

This study revealed that key performance indicators (KPIs), including Door-to-Doctor Time, Doctor-to-Decision Time, Decision-to-Disposition Time, and Door-to-Disposition Time, have improved following the implementation of the Ada'a Health Program. The reduction in patient wait times suggests that data-driven decision-making has played a pivotal role in enhancing efficiency. Several measures could further optimize ED performance, including expanding consultation areas, redesigning patient flow pathways, implementing digital triage solutions, and integrating real-time patient tracking systems. Previous research has also shown that structural and procedural reorganization of EDs can significantly reduce wait times and improve patient outcomes.[7,10]

Multiple factors contribute to increased ED processing times, including disease severity, patient comorbidities, staff availability, and the efficiency of medical interventions. Critically ill patients require more comprehensive evaluations, which may extend decision and disposition times. Additionally, the clinical experience of ED physicians and nurses directly influences patient flow. This highlights the importance of continuous training, workforce optimization, and efficient utilization of available healthcare resources.

Overcrowding remains a significant challenge in emergency departments, limiting resource utilization and increasing patient dissatisfaction. Implementing Lean methodology has been widely recognized as an effective approach to eliminating inefficiencies and non-value-added tasks. However, the success of Lean principles depends on the identification of wasteful activities, appropriate use of digital solutions, and effective workflow restructuring. The findings of this study suggest that applying Lean techniques alongside big data analytics can lead to substantial improvements in ED efficiency.[11]

Emergency departments differ in terms of management structures, resource allocation, and patient demographics. However, the core operational processes remain similar across most healthcare facilities. The Ada'a Health Program has demonstrated substantial improvements in patient care efficiency, with more than 85% of ED patients being treated within four hours. This program, originally launched to enhance healthcare delivery during the Hajj season, has since been expanded to over 150 hospitals and 730 primary care centers across Saudi Arabia. The program's effectiveness is evident in the standardization of KPIs, real-time data monitoring, and performance-driven decision-making.

The Ada'a Health programme in Saudi Arabia was launched to improve healthcare delivery during the Hajj season by collecting day-to-day activity. The Ministry of Health (MOH) launched the Ada'a Health programme as a significant enabler to improve hospitals and specialized medical centers' performance as a strategic objective by maximizing operational efficiency and productivity, improving hospital teams, skills, and capability, and achieving balance across productivity, economy, available resources, staff satisfaction, retention, and patient satisfaction.[12]

The global recognition of the Ada'a Health Program, including the 2018 MCA "International Project of the Year" award, further highlights its impact on healthcare optimization. By leveraging real-time data analytics, hospital administrators can make proactive adjustments, ensuring sustained operational efficiency and patient satisfaction. This study underscores the importance of continuous refinement of big data strategies, integration of updated predictive analytics, and workforce capacity-building to further optimize emergency department services in Saudi Arabia.

Limitations

Interpreting this study's conclusions took into account certain constraints. Consequently, future studies must have a longer study period and larger sample size to generalize results to other emergency rooms in Saudi Arabia and worldwide. However, the study evaluated the process in an uncontrolled emergency room environment. Emergency departments are also uncertain since patients arrive at different times with different needs. Emergency services may increase during long public holidays, especially Hajj. This study's hospital sample may cause selection bias.

Conclusion

This study highlights the significant role of big data analytics in enhancing emergency department (ED) operational efficiency within Saudi Ministry of Health (MOH) hospitals. By leveraging the Ada'a Health Program, substantial improvements in key performance indicators (KPIs), including Door-to-Doctor Time, Doctor-to-Decision Time, Decision-to-Disposition Time, and Door-to-Disposition Time, were observed. The results indicate that integrating real-time data insights has led to reduced patient wait times, streamlined workflow processes, and optimized resource allocation, ultimately improving service quality and patient outcomes.

Beyond immediate efficiency gains, the study underscores the broader impact of data-driven decision-making in healthcare management. The findings suggest that structured big data integration, when combined with Lean methodology and digital performance tracking, can create sustainable improvements in ED operations. The Ada'a Health Program serves as a replicable model for other healthcare systems seeking to enhance patient flow, minimize delays, and optimize workforce utilization.

Additionally, the study acknowledges the importance of continuous refinement and future innovations, including AI-driven predictive analytics and advanced automation in patient triage and resource allocation. Future research should explore the long-term sustainability of big data initiatives, their scalability across diverse healthcare settings, and their potential in addressing persistent challenges such as ED overcrowding, resource constraints, and clinical decision-making inefficiencies. By continuing to refine big data strategies, healthcare administrators can ensure that emergency departments remain responsive, efficient, and patient-centered in delivering high-quality care.

Disclosure

The authors report no conflicts of interest in this work.

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