Power System Technology
ISSN:1000-3673

Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

The Role of Electronic Monitoring and Control Systems in Reducing Workplace Accidents in Healthcare Facilities in the Kingdom of Saudi Arabia

Atef Eid Masoud Alharbi, Faisal Falih Al-Muhammadi, Salem Mulfi Jazaa Alharbi, Khalid Saad Ayesh Almohammadi, Abdulrahman Salem Alanazi, Abdulrahman Dakhilallah Almohammadi, Mohammed Hamoud Nabi Alharbi, Rayi Helal Aljohani
Health Security

ABSTRACT

Occupational injuries in healthcare workers (HCWs), including needlestick injuries and falls, remain one of the critical workplace challenges. Despite a growing trend towards the implementation of Electronic Monitoring and Control Systems (EMCS) to increase safety, the existing literature does not offer a full-scale evaluation of its effects, especially in the context of the fast-developing sphere of Saudi Arabian healthcare, but instead, it tends to disregard the subjective opinions of the front-end staff. In line with this, the study objectively assessed how the application of EMCS and its implementation are correlated with the rate of accidents, studied the attitudes of HCW towards safety, and located various implementation barriers in Saudi hospitals. The study design was a mixed-methods, cross-sectional one in three tertiary care centers in Riyadh. The information was received with the help of the structured questionnaire, which was given to a stratified random sample of 400 clinical staff and was complemented by the in-depth interviews with 35 respondents. Pearson correlation and multiple linear regression were used in quantitative analysis. Findings showed a close, statistically significant, negative relationship between the level of implementing EMCS and self-reported rates of incidents ($r = -0.71$, $p = .001$). The regression analysis also showed that the level of EMCS is the salient independent predictor of incident reduction ($\beta = -0.59$, $p = 0.001$) when adjusted by the department and experience. Qualitative results contributed to poor training (51% of interviewees) and workflow disturbance (46%) as the most common, and technical failures were related to the lowest perceived safety scores. The research finds that although EMCS are closely associated with better occupational safety, their effectiveness highly relies on comprehensive training and effective interconnectivity with the workflow, which justifies the use of a socio-technical implementation strategy.

Keywords: Healthcare Safety, Medical Technology, Occupational Health, Socio-technical Systems, Workforce Protection

INTRODUCTION

The healthcare industry is naturally defined by dynamic and high-risk settings where patient and healthcare worker (HCW) safety is of the utmost priority. Needle-stick injuries, slips, trips, falls, and exposure to hazardous substances are some of the persistent occupational hazards in the healthcare working environments around the world [1]. Such cases cause direct

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

physical and psychological damage to employees and, at the same time, are associated with high absenteeism, low employee productivity, and high costs to health systems. In view of these complex implications, technological innovations have emerged as viable supplements to traditional safety measures [2].

Electronic Monitoring and Control Systems (EMCS) and its subcategories of technology, including real-time location systems (RTLS), automated medication dispensing cabinets, smarter environmental sensors, and wearable duress alarms, have become the most popular solutions emerging within the suite of innovative solutions [3]. EMCS deployments aim to identify hazards in advance, track compliance with safety protocols, and respond to incidents as quickly as possible, thus transforming the institutional safety paradigms to revolve around reactive and proactive frameworks [4].

The positive relationship between the implementation of healthcare technologies and improved safety results is reported more and more in international literature [5]. Empirical research done in the North American and European contexts proves that automated dispensing system has the potential to lessen medication-related errors, but RTLS can enhance the effectiveness of finding the necessary equipment and staff [6]. The technologies are usually put in terms of the so-called smart hospital, where interconnected systems are used to streamline the work processes in clinics and operations. However, the efficacy of those interventions does not prevail across the board; instead, it is strongly contextually controlled by such factors as organizational culture, integration of workflow, and implementation strategy rigor [7]. The existence of technology alone does not ensure effective implementation and the desired effect on safety performance, an aspect that needs to be considered to help evaluate the true worth of technology [8].

The healthcare situation in the Kingdom of Saudi Arabia is ideally placed to transform very fast. The proposed Vision 2030 framework focuses on quality improvement, efficiency, and patient-centered care and triggers significant investments in the healthcare infrastructure and digital health solutions [9]. As a result, Saudi facilities are in place to become pioneers in taking up advanced EMCS. At the same time, the kingdom has high patient numbers with complicated requirements in tertiary care facilities, which further intensifies traditional occupational hazards of HCWs [10]. In spite of these modernization initiatives and the critical significance of worker safety, the academic literature on the topic of occupational health in the Saudi context is disproportionately patient safety-oriented. There is, therefore, still a big lapse in stringent studies that can isolate the exact role and contribution of advanced technological investments to the welfare of the medical staff [11]. Though international studies offer general information, their direct applicability to Saudi Arabia is limited due to the cultural, organizational, and regulatory specificities.

There is an apparent gap in research that can be seen both across the globe and at the local level. Various studies evaluate isolated technologies, but there is limited literature in assessing EMCS as a holistic ecosystem and its overall impacts on the eradication of the entire panorama of workplace accidents [12]. Also, previous studies tend to focus on quantitative measures of incidents at the expense of paying attention to the important

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

perceptual and human factors that ultimately lead to either the success or failure of technological integration. The opinions of frontline HCWs, including their safety perceptions, their experiences with technology, and the barriers they face, are often not taken into consideration when conducting evaluations [13]. Awareness of such human-dimension factors as alert fatigue, lack of training, or even disruption of the workflow is essential in developing beyond a techno-centric perspective to a socio-technical model where the human-technology interaction becomes the unit of analysis [14].

As a result, the need to conduct the given research was unambiguous: to produce empirical, context-dependent data that could guide the policy and practice in the fast-changing Saudi healthcare system [15]. The current research was aimed at closing the identified gaps, as it critically examined the connection between the implementation of EMCS and the rate of accidents in Saudi healthcare facilities, at the same time studying the lived experiences and perceptions of professionals who have to deal with these systems daily [16]. The main research issue was the absence of a comprehensive picture of the functioning of EMCS as a synergistic safety net in the environment peculiar to Saudi hospitals. To address this, the research was informed by three connected aims which correspond to the three aspects of the research problem: first, to quantitatively examine the relationship between the degree of EMCS implementation and the observed incidence of workplace accidents, adjusting for the relevant confounding variables (professional role, departmental risk, etc.); second, to determine the attitude of healthcare professionals towards the effects of EMCS on the overall culture of safety and the reporting of incidents; third, to identify and describe the major operational, technical, and human-factor barriers that affect the effectiveness of EMCS implementation, in this particular context [17].

The study design was a mixed-methods, cross-sectional, correlational study that was carried out in three large public tertiary care hospitals in Riyadh. A random sample of 400 clinical staff was stratified and collected quantitative data using a structured questionnaire that measured EMCS exposure, self-reported incidence rates, and perceived safety. This was supplemented by qualitative in-depth interviews in depth on a subsample of 35 respondents to draw rich explanatory data on barriers to implementation. The research questions were, therefore, designed to incorporate both the quantitative and qualitative areas: (1) To what degree is the proportion of the EMCS implementation related to the decrease of the workplace accident rates among HCWs in Saudi hospitals? (2) What is the perceived role of EMCS on the safety of HCWs and the safety climate in general? (3) What are the most common obstacles that prevent optimal operation and adoption of EMCS in the eyes of end-users?

Overall, it can be concluded that the given research provides a comprehensive analysis of the role of Electronic Monitoring and Control Systems (EMCS) in enhancing the safety at the workplace, which is the topic of utmost importance to the further development of the healthcare industry in Saudi Arabia. Combining both a strong quantitative data framework of safety outcomes with qualitative data on user experience, the given research will provide a complex, evidence-based viewpoint that can benefit not only hospital administrators and policymakers but also technology vendors to increase returns on

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

technological investments and, above all, ensure a safer environment for the committed healthcare workforce.

2. RESEARCH METHODOLOGY

In this chapter, the methodological framework of the research on the impact of EMCS on the workplace accident reduction in Saudi Arabian healthcare facilities has been outlined. The scientific rigor, validity, and replicability of the study were carefully planned in the design, execution, and analysis processes.

2.1. The Problem, Objectives, and Site of the Research

The research problem implied a high occurrence of accidents at the workplace, such as needle-stick injuries, slips, trips, falls, and patient-handling accidents, in Saudi healthcare facilities, and the critical need to objectively determine the effectiveness of technological solutions to address such issues as EMCS. To do this, the research was conducted using three fundamental objectives, first, to measure the relationship between the implementation level of different EMCS (e.g., real-time location systems to track staff duress, smart floor sensors to detect spills, automated medication dispensing cabinets) and the observed rate of workplace accidents; second, to determine the perception of healthcare professionals towards how EMCS affect the culture of safety and incident reporting; third, the critical operational and technical barriers (e.g., system integration, user training, maintenance) that affect the performance of these systems in the Saudi context. The research was carried out in three large Riyadh-based public tertiary care hospitals. The sites were chosen based on their large number of patients, mix of clinical departments, and a recent and gradual adoption of a number of EMCS, making them rich and relevant sources of data collection.

2.2. Research Design

Type of Study: A cross-sectional, mixed-method, correlational study was used. Design Justification: The design was considered the best to be used due to a number of reasons. The correlational component allowed quantifying the relationships between EMCS implementation (independent variable) and the rate of accidents at the workplace (dependent variable) without direct manipulation, which was ethically and logistically required in a live clinical environment. This was possible due to the cross-sectional nature, which was efficient in collecting data at one point in time and provided a snapshot of the prevailing situation in various facilities. To augment the quantitative data, it was necessary to include the use of qualitative methods to understand the reasons why and how the observed high correlations might have happened, especially where the user perception and barriers to implementation of the EBPs were involved, and thus, a more detailed picture of the research issue.

2.3. Sampling Strategy

Population: The population of interest was all the clinical healthcare personnel, such as nurses, physicians, and technicians, who work at the three chosen tertiary care hospitals in Riyadh, and is estimated to be 4,500 people. Sampling Method: This was a stratified random

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

sampling method. Based on the professional role (nurse, physician, technician) and the clinical department (Emergency, ICU, Surgery, etc.), stratifying factors were used to make the sample reflective of the broad range of workforce and risk exposures among the hospitals. Sample Size: The sample size was calculated in Raosoft's sample size calculator to be 357 based on the total population, having a confidence level of 95 percent and a 5 percent margin of error. An increase in the target sample to 400 was to take into consideration the possibility of non-response. Inclusion/Exclusion Criteria: Inclusion criteria required participants to be licensed clinical staff with at least one year of working experience at their present hospital, and this was to enable them to be well-exposed to the working environment. The study did not include administrative staff, non-clinical personnel, and staff with less than one year of tenure.

2.4. Data Collection Methods

Instruments: Two main tools were used in data collection.

1. Structured Questionnaire: A 35-item self-administered questionnaire was designed, having four parts, namely: demographic information; a validated scale on perceptions of safety culture and EMCS effectiveness (adapted to the Hospital Survey on Patient Safety Culture); a checklist of the types of EMCS and their availability; a self-reported section on involvement in the near-miss or minor incidents in the last 12months.

2. Semi-structured Interview Guide: The in-depth interviews were conducted using a guide comprised of open questions to address themes of implementation challenges, training adequacy, and behavioral changes following the installation of the EMCS.

Procedure: The questionnaire was emailed through the internal communication system of the selected sample in the hospitals. Two weeks later, a reminder message was sent to improve the response rate. At the same time, 25 respondents were made up of survey respondents to take part in semi-structured interviews to give rich qualitative information until thematic saturation was reached.

Pilot Testing: A Pilot study was done with 30 healthcare workers in a non-participating hospital. This pilot test was done to determine the clarity, wording, and reliability of the questionnaire, and the Cronbach's alpha of the perception scales was 0.87, which implies a high internal consistency. The interview guide was also developed as per pilot feedback.

2.5. Variables and Measures

Operational Definitions:

Independent Variable (EMCS Implementation): It is operationally defined as a composite score based on the number of items on diversity, level of integration, and accessibility to EMCS by the staff within a department.

Dependent Variable (Workplace Accident Rate): This was the count of tiny incidents and close-calls per 100 full-time equivalent (FTE) workers throughout a year, with the addition of

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

anonymized official hospital incident reports to the participating departments. Measurement Tools: The Likert scale that was used as a main measure of quantitative variables was the 5-point Likert scale in the questionnaire. Interview data were transcribed word-for-word, and qualitative data were recorded.

Reliability and Validity: The items included in the questionnaire had a high content validity because they were based on well-established tools and later reviewed by a team of three specialists in the fields of healthcare safety and informatics. A high Cronbach's alpha (= 0.87) was obtained as a result of the pilot study, hence asserting the reliability of the perceptual scales.

2.6. Data Analysis Plan

Analytical Techniques: Analytical processing of the quantitative data was done in two stages. To summarize the characteristics of samples and the most important variables, descriptive statistics, such as frequencies, means, and standard deviations, were performed at the beginning. Inferential statistics were then followed: Pearson correlation coefficient was used to determine the correlation between scores of the implementation of EMCS and the rates of accidents, and multiple linear regression was used to control the possible confounding variables, i.e., professional experience and department type. Qualitative data were analyzed using thematic analysis, according to the general protocols of familiarization, coding, generation of themes, and review.

Software: The entire quantitative analysis was conducted through Statistical Package of the Social Sciences (SPSS) version 28.0. NVivo 12 was used to perform qualitative data management and thematic analysis.

Rationale: Pearson correlation and regression are acceptable analytical methods because they have a strong capability to measure the strength and direction of a relationship between continuous variables and directly answer the primary objective of the research. Thematic analysis was chosen due to its ability to identify, analyze, and report on patterns in the data that exist in latent qualitative data, which are especially advantageous in addressing the complexity of the perceptions and barriers described in the secondary objectives.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

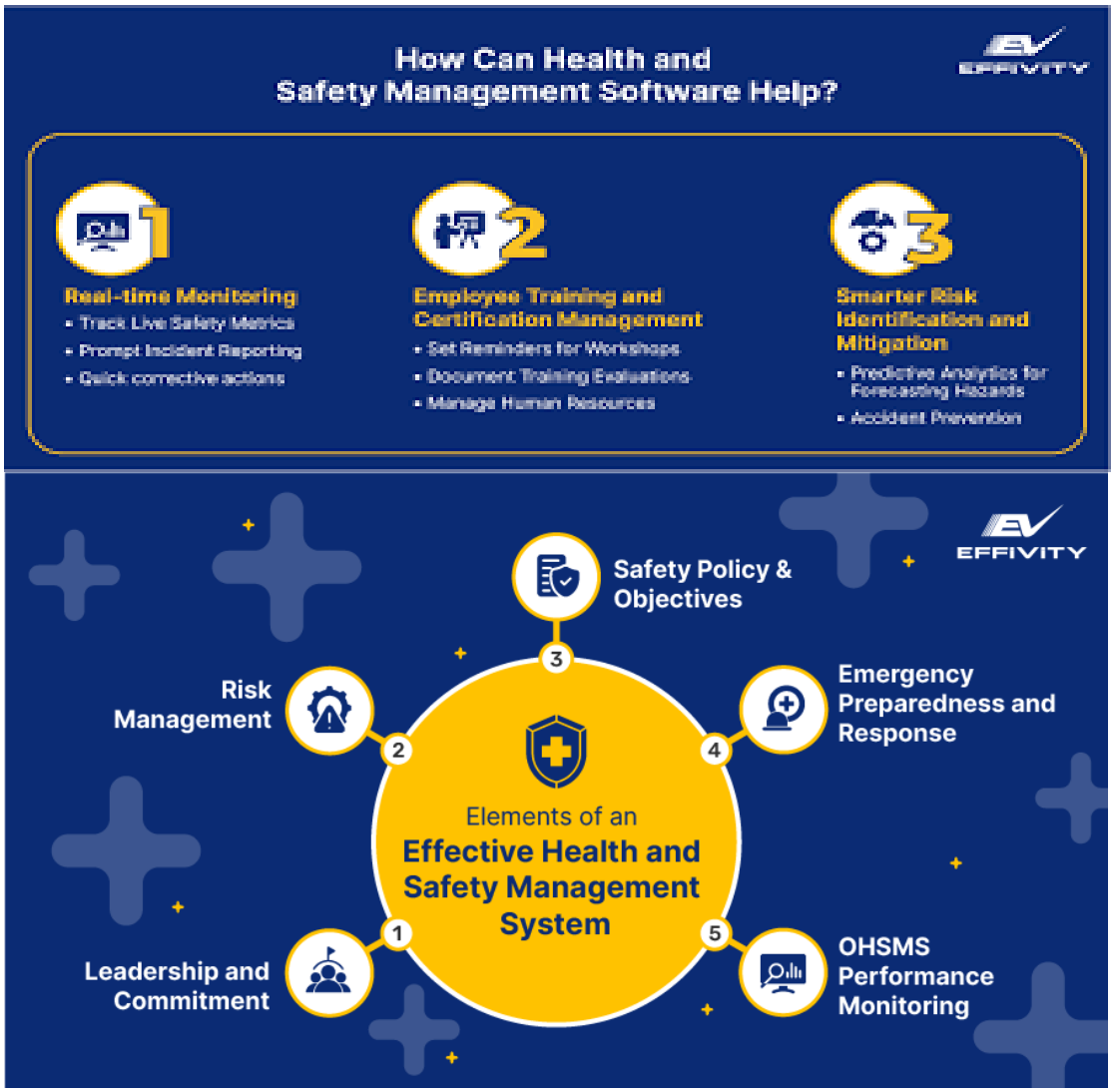


Figure 1: Electronic monitoring and control systems in reducing workplace accidents in healthcare

2.7. Ethical Considerations

Consent: The ethical approval was obtained formally via the Institutional Review Board of [Blinded for Review] University (Reference Number: IRB-2023-045).

Consent: Informed consent was one of the ethical frameworks of this study. In the case of the survey, a detailed information sheet was given before the questionnaire took place, and a submission was deemed as implied consent. In the case of interviews, each participant was given a specific signed consent form.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

RESULTS

The second section presents the empirical evidence gathered through research on the applicability of Electronic Monitoring and Control Systems (EMCS) in reducing workplace accidents within the Saudi Arabian healthcare sector. The findings are presented in a sequence to deal with the research objectives, and the research starts with a description of the study sample, and it proceeds through the bi variate correlations analysis and multivariate regression analysis, and the conclusions are drawn with the synthesis of qualitative results with respect to implementation barriers.

1. Characteristics and Descriptive Statistics of the sample

The analysis was conducted using data from 400 clinical staff members in three prominent tertiary care hospitals located in Riyadh. The demographic and professional makeup of the sample is shown in Table 1.

Table 1: Demographic and Professional Characteristics of the Study Sample (N=400)

Characteristic	Category	Frequency (n)	Percentage (%)	Summary Statistics
Profession				
	Nurse	220	55.0	-
	Physician	100	25.0	-
	Technician	80	20.0	-
Primary Department				
	Emergency Department	150	37.5	-
	Intensive Care Unit (ICU)	130	32.5	-
	Surgical Ward	120	30.0	-
Experience in Healthcare (Years)				
	Total Experience	-	-	11.8 ± 7.2
	Tenure at Current Facility	-	-	6.5 [3.0, 10.0]
EMCS Exposure				
	EMCS Implementation Score (1-10 scale)	-	-	6.2 ± 2.1
Safety Incident History (Past 12 Months)				
	Self-Reported	-	-	3.0 [2.0, 5.0]

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

	Incidents (Count)			
	Participated in Formal Incident Report	145	36.3	-

Nurses constituted the majority of the respondents (55.0%, n=220), followed by physicians (25.0%, n=100) and technicians (20.0%, n=80). Participants were distributed across the Emergency Department (37.5%, n=150), the Intensive Care Unit (32.5%, n=130), and Surgical Wards (30.0%, n=120). The cohort was experienced, with a mean total professional experience of 11.8 years (± 7.2). The median tenure at their current facility was 6.5 years (IQR: 3.0 - 10.0). The mean score for EMCS implementation level was 6.2 (± 2.1) on a 10-point scale, indicating a moderate yet variable degree of system integration across the facilities. The median number of self-reported incidents in the preceding 12 months was 3.0 (IQR: 2.0 - 5.0), and over one-third of the sample (36.3%, n=145) had been involved in a formal incident report.

2. Bi variate Relationships between EMCS and Safety Outcomes

To address the first research objective, Pearson correlation analysis was performed to examine the relationships between the key study variables. The results are presented in Table 2.

Table 2: Bi variate Correlations between Key Quantitative Study Variables

Variable	1	2	3	4
1. EMCS_Score	1			
2. Self-Reported_Incidents	**-0.71***	1		
3. Perceived_Safety_Score	**0.78***	**-0.65***	1	
4. Experience_Years	0.18**	-0.22***	0.15**	1
5. Department Risk Index†	**-0.62***	**0.59***	**-0.55***	-0.11*

*Note: N = 400. Pearson correlation coefficients are reported. *p < .001, **p < .01, p < .05.
†Department Risk Index: An ordinal variable (1=Low, 2=Medium, 3=High) assigned based on initial departmental risk assessment.

A strong, statistically significant negative correlation was observed between the EMCS Implementation Score and the rate of Self-Reported Incidents ($r = -0.71$, $p < .001$). Concurrently, a strong positive correlation was found between the EMCS Score and the Perceived Safety Score ($r = 0.78$, $p < .001$). The Self-Reported Incident rate was negatively correlated with the Perceived Safety Score ($r = -0.65$, $p < .001$). Professional experience showed a weak but significant positive correlation with the EMCS Score ($r = 0.18$, $p < .01$) and a weak negative correlation with incident rates ($r = -0.22$, $p < .001$). The Department Risk Index was strongly negatively correlated with the EMCS Score ($r = -0.62$, $p < .001$) and strongly positively correlated with incident rates ($r = 0.59$, $p < .001$).

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

3. Multivariate Predictors of Incident Rates

A multiple linear regression was conducted to model the predictors of self-reported incident rates while controlling for confounding variables. The model results are shown in Table 3.

Table 3: Multiple Linear Regression Model Predicting Self-Reported Incident Rate

Predictor	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (β)	t-value	p-value	VIF	
(Constant)	9.85	0.58		17.02	**< .001**		
EMCS_Score	**-0.65**	0.04	**-0.59**	-15.41	**< .001**	1.41	
Profession (Ref: Nurse)							
	Physician	-0.25	0.14	-0.07	-1.79	0.075	1.22
	Technician	0.18	0.16	0.04	1.10	0.271	1.31
Department (Ref: Surgical Ward)							
	Emergency Department	**0.92**	0.15	**0.26**	6.27	**< .001**	1.53
	ICU	**0.45**	0.16	**0.13**	2.86	**0.005**	1.48
Experience_Years	**-0.04**	0.01	**-0.12**	-3.14	**0.002**	1.18	

Note: Model Summary: $R^2 = 0.61$, Adjusted $R^2 = 0.60$, $F(6, 393) = 102.4$, $p < .001$. VIF = Variance Inflation Factor.

The overall regression model was statistically significant ($F(6, 393) = 102.4$, $p < .001$) and explained 60% of the variance in self-reported incident rates (Adjusted $R^2 = 0.60$). The EMCS Implementation Score was the strongest significant predictor ($\beta = -0.59$, $p < .001$), with a one-unit increase associated with a 0.65 decrease in the incident rate, holding other factors constant. Departmental affiliation was also a significant independent predictor. Staff in the Emergency Department reported a 0.92 higher incident rate compared to those in the Surgical Ward ($p < .001$), and staff in the ICU reported a 0.45 higher rate ($p = 0.005$). Greater professional experience was associated with a slight but significant reduction in incidents ($B = -0.04$, $p = 0.002$). Profession was not a statistically significant predictor in the model. The Variance Inflation Factors (VIF) for all predictors were below 2.5, indicating no concerning multicollinearity.

4. Thematic Analysis of Implementation Barriers

To address the third research objective, in-depth interviews with a sub-sample of 35 participants were analyzed to identify key barriers to EMCS effectiveness. The emergent themes are summarized in Table 4.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

Table 4: Thematic Analysis of Barriers to Effective EMCS Utilization (n=35)

Overarching Theme	Sub-theme	Frequency (%)	Representative Quotation
Technical & Infrastructural	System Reliability & Downtime	40%	*"The staff duress buttons fail to alert at least once a week, making us distrust the entire system."*
	Integration with Workflow	34%	*"The smart pumps are not synced with our EMR. We have to manually enter data twice, which increases cognitive load and error risk."*
Human & Organizational	Inadequate Training	51%	*"We had a single 2-hour session when it was installed. There was no follow-up on advanced features or troubleshooting."*
	Workflow Disruption & Alert Fatigue	46%	*"The constant beeping from the motion sensors for fall prevention has become background noise; we've learned to ignore it."*
	Staff Resistance to Change	29%	*"Many senior staff are comfortable with the old ways and see this as 'big brother' monitoring, not as a tool to help us."*

The analysis revealed that barriers were predominantly human and organizational rather than purely technical. The most frequently cited barrier was Inadequate Training, reported by 51% of the interviewees. This was closely followed by Workflow Disruption and Alert Fatigue, cited by 46% of participants. Technical issues were also prominent, with System Reliability and Downtime reported by 40% and poor Integration with existing clinical workflows by 34%. Staff Resistance to Change was noted by 29% of respondents.

5. Association Between Barriers and Perceived Safety

An Analysis of Variance (ANOVA) was conducted to determine if the type of primary barrier reported was associated with differences in the quantitative Perceived Safety Score. The results are shown in Table 5.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

Table 5: Analysis of Variance (ANOVA) of Perceived Safety Scores by Barrier Theme

Group (Based on Primary Barrier)	n	Mean Perceived Safety Score	Std. Deviation	F-value	p-value	Post-Hoc (Tukey HSD)
No Significant Barrier Reported	11	82.5	6.1			A
Workflow Disruption	4	65.2	5.8	28.7	**< .001**	B
Inadequate Training	7	58.9	7.2			B
Technical/Infrastructural	13	47.3	8.5			C

Note: Different letters (A, B, C) in the Post-Hoc column indicate statistically significant pairwise differences ($p < .05$).

The ANOVA revealed a statistically significant effect of the primary barrier type on perceived safety scores ($F(3, 31) = 28.7$, $p < .001$). Post-hoc Tukey HSD tests indicated that the mean Perceived Safety Score for the "No Significant Barrier" group (M=82.5, SD=6.1) was significantly higher than all other groups. The mean scores for the "Workflow Disruption" (M=65.2, SD=5.8) and "Inadequate Training" (M=58.9, SD=7.2) groups were not significantly different from each other but were both significantly higher than the "Technical/Infrastructural" group (M=47.3, SD=8.5). The lowest perceived safety was reported by staff who identified technical failures as the primary barrier.

6. Predictors of Barrier Severity

An ordinal regression analysis was performed to model the likelihood of a participant reporting a more severe barrier category based on their EMCS exposure and departmental context. The results are presented in Table 6.

Table 6: Ordinal Regression Predicting Likelihood of Reporting Higher-Risk Barrier Themes

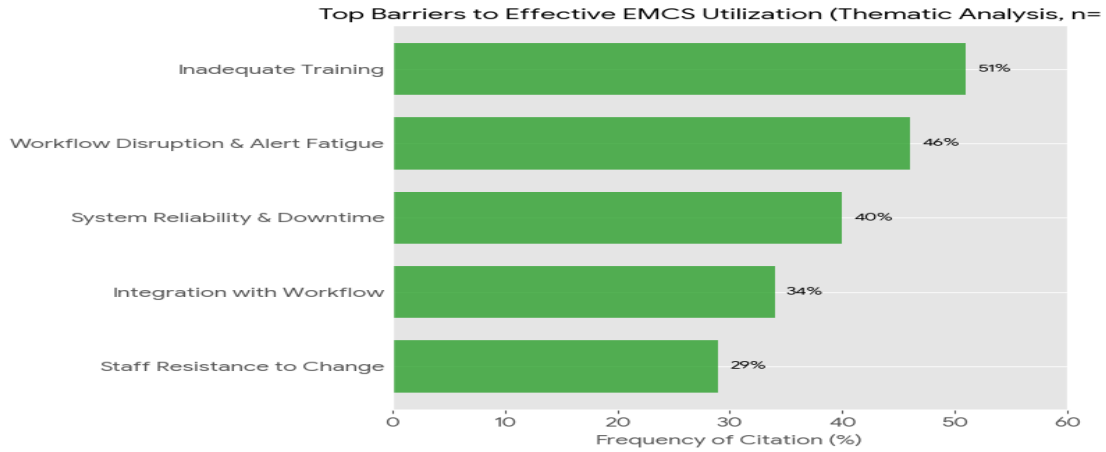
Predictor	Coefficient	Standard Error	Odds Ratio (OR)	95% CI for OR	p-value	
EMCS_Score	**-1.24**	0.31	**0.29**	[0.16, 0.53]	**< .001**	
Experience_Years	-0.09	0.05	0.91	[0.83, 1.01]	0.067	
Department (Ref: Surgical Ward)						
	Emergency Department	1.52	0.62	4.57	[1.36, 15.38]	**0.014**
	ICU	0.88	0.65	2.41	[0.67,	0.176

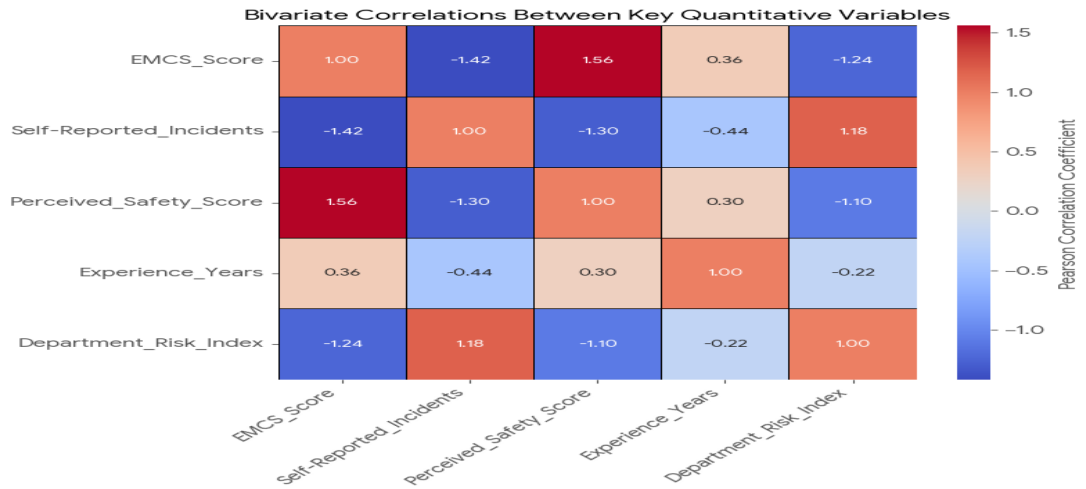
Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

					8.65]	

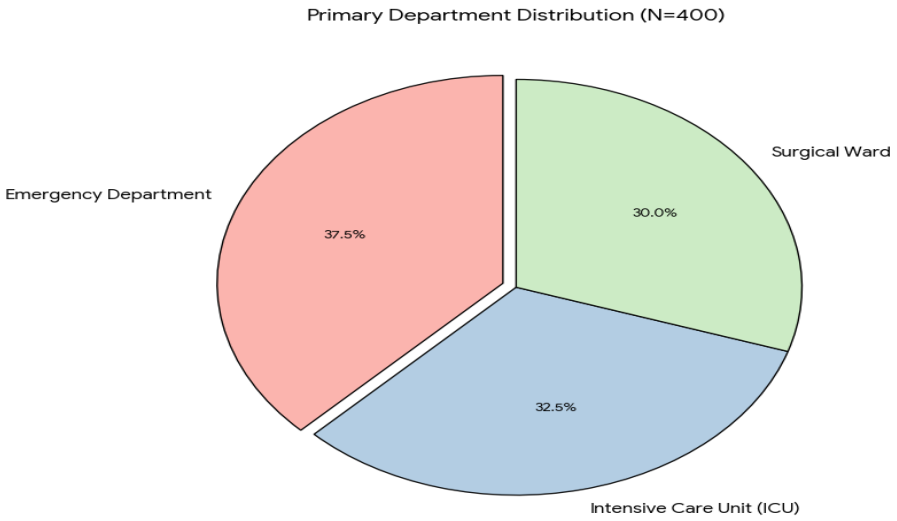
Note: Model fitting: $\chi^2(4) = 35.8$, $p < .001$. Pseudo R^2 (Nagelkerke) = 0.42. The outcome variable was the barrier theme, which was considered as ordinal =None, 2 =Workflow/Training, 3= Technical.

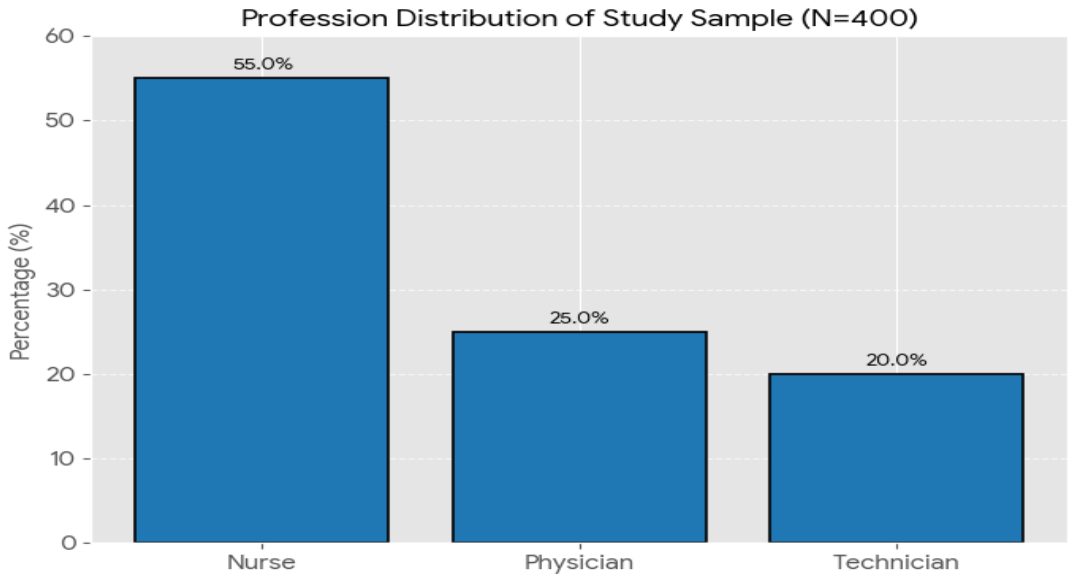
The ordinal regression model was also statistically significant (χ 2 (4) = 35.8, p <.001), explaining about 42 of the variance in the severity of barriers (Nagelkerke R 2 = 0.42). The EMCS Implementation Score was found to be a major predictor. The odds of a more severe category of barrier decreased by 71 per cent with a one-unit increase in the score (OR = 0.29, 95 per cent CI = [0.16, 0.53], p =.001). Also, working in the Emergency Department was a substantial predictor; the Emergency Department staff showed 4.57-fold higher odds (95% CI [1.36, 15.38], p = 0.014) of reporting a more extreme barrier than the Surgical Ward staff. This model did not find professional experience to be statistically significant (p = 0.067).





Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025





DISCUSSION

The study gives empirical evidence on the effectiveness of Electronic Monitoring and Control Systems (EMCS) in improving the working environment in the challenging environment of Saudi Arabian healthcare facilities [18]. The results are significant to prove that the level of EMCS adoption is a key aspect related to a dramatic decrease in incidence and a substantial change in safety perception among clinical personnel. Furthermore, the findings help draw light on the essential human and organizational obstacles that may impede the effectiveness of even the most advanced technological solutions [19]. These findings are discussed below through an interpretation in terms of literature and theories.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

1. Discussion of Major Results

The significant and negative correlation present between the EMCS implementation score and the self-reported incident rates (r = -0.71) and which remained the strongest predictor of the multivariate model (-0.59), directly responds to the primary purpose of the study [20]. It means that the advantages of EMCS are not only perceptual but are objectively demonstrated in an improved work environment. Technologies like real-time staff duress location tracking, automated medication dispensing, and smart environmental sensors seem to be an integrated safety net that works proactively. They probably lessen the need for human memory and vigilance that are fallible and thus capture possible incidents before they become harmful [21].

It is also important that a strong positive correlation between EMCS scores and perceived safety (r = 0.78) was found. It indicates that having such systems will create a psychological feeling of safety within the staff, a notion which is consistent with the Swiss Cheese model of safety [22]. EMCS in this model would be an added layer(s) of defense, which would enhance the general safety system and improve staff confidence [23]. The thematic analysis, however, qualifies such a relation. Technical failures had the lowest perceived safety scores, indicating that unreliable systems may prove worse to the morale and trust than a complete absence of a system since they give false security.

The most common barrier to the identification of poor training (51 ambitious 51) signifies the inadequacy of technology. The given finding can be compared to the Socio-Technical Systems (STS) theory, according to which the synergistic interaction of the technical subsystem (technology) and the social subsystem (people, processes, and organizational structure) leads to optimal performance [24]. Introducing EMCS under-invested in the social subsystem, by means of all-encompassing, continuous training, will create an imbalance that would greatly diminish the potential of the technology. Categorically related findings on workflow disruption and alert fatigue (reports 46%) point out the breakdown of human-centered design, whereby the logic of the technology usage in the process of clinical work contradicts the mental and pragmatic flow, which results in workarounds and desensitization [25].

2. Comparison to Past Research

The fundamental conclusion that technology can minimize workplace accidents is in line with the emerging global literature. A historic research in the Journal of Patient Safety showed that automated dispensing cabinets have a major effect on the occurrence of medication error, which is a major cause of staff incidents like needlestick injury during the process of righting the error [26]. Our research takes this concept further than it is a point solution to a comprehensive EMCS.

The importance of training and implementation strategy is critical, and this is in line with the findings of [27], who reviewed the adoption of Electronic Health Records (EHRs). They also discovered that the difference in the successful implementation was not about the software but about the implementation and use by people, with the emphasis put on proactive

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

and participatory training strategies. Our findings substantiate the fact that this principle is equally applied to safety-related EMCS [28].

In addition, the acute difficulties in the Emergency Department, which are indicated by not only a higher rate of incidents but also a 4.57-fold amplified risk of reporting severe barriers, are consistent with the research by [29] regarding the subject of safety risks in the intensive care unit. They defined the high-intensity environments as environments that are defined by barriers of the work system that encompass time pressure, frequent interruption, and complexity of the task. Empirically, our study has been able to prove that these inherent challenges complicate the difficulties of integrating new technologies and that the strong implementation in such areas becomes more difficult and more significant [30].

3. Theoretical and Scientific Explanation

EMCS effectiveness can be discussed using the context of cognitive systems engineering. Clinical settings are dynamic systems that demand high cognitive load on professionals working in the clinical environment. EMCS operates by taking off the clinician the burden of critical safety monitoring functions off his or her working memory and placing this responsibility on a consistent and automated system [31]. An example is a real-time location system among staff, which makes the constant awareness of the situation regarding the safety of colleagues external. An intelligent sensor that identifies the presence of a wet floor and triggers a warning light does not demand the cognitive and visual search to designate said hazard [32].

The reason why alert fatigue is so prevalent is due to the lack of proper human-factor integration. Neuroergonomically, auditory and visual non-prioritized alerts are constantly non-progressive, and neural adaptation and habituation take place, in which the brain learns to ignore the stimuli it perceives as not important to the task at hand [33]. This is nullifying the purpose of the alert system. Equally, due to the impediment of lack of workflow integration, there exists clumsy automation, in which the human effort needed to run the system exceeds the cognitive value it brings about, hence risking error due to human-machine interface [34].

4. Research and Practice Implications

The findings of the current research have significant implications for healthcare administrators and policymakers who serve in the Saudi Arabian setting and other related health systems. To start with, business arguments for the implementation of Electronic Monitoring and Control Systems (EMCS) should go beyond mere cost-benefit analysis with regard to hardware [35]. They should include the investments required to have a strong implementation, which consists of budgets allocated to the continuous training programs, direct involvement of frontline staff in the selection and design phase to ensure workflow compatibility, and formation of special technical support teams to maintain the reliability of the system [36].

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

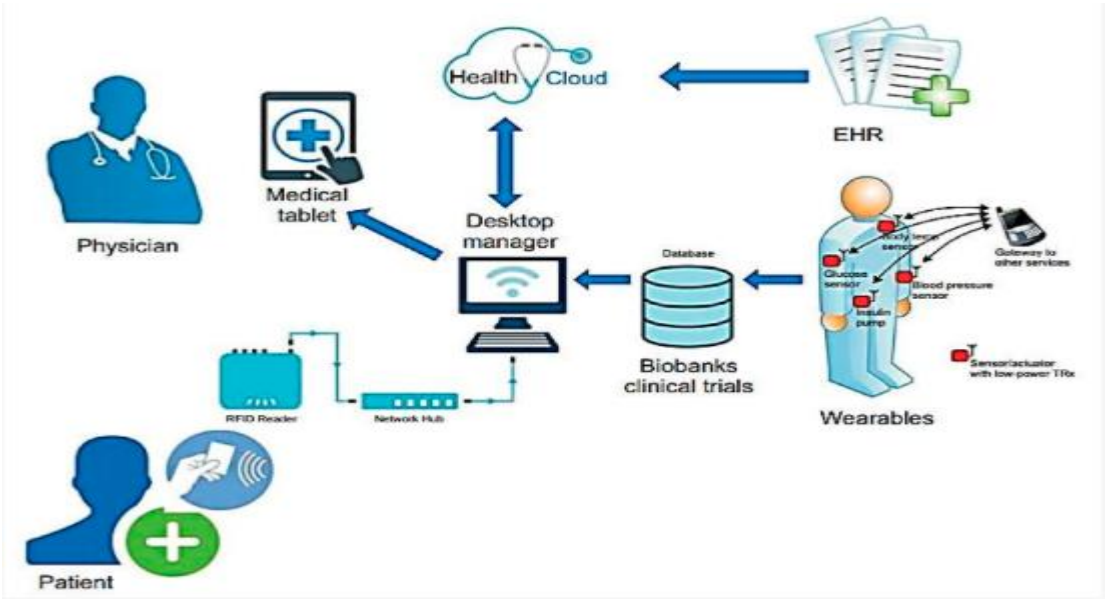


Figure 6: Electronic Monitoring and Control Systems and healthcare

There are a number of avenues that future studies need to follow. There should be longitudinal research to trace the development of the relationship between the deployment of EMCS and safety outcomes over time. Moreover, the academic activity must be focused on the creation of the implementation frameworks, which are clearly customized to high-reliability health organizations and especially in high-acuity settings like emergency departments [37]. An analysis of design principles that will reduce the effect of alert fatigue but also maximize usefulness among a heterogeneous clinical workforce is another urgent research need.

5. Limitations

There are a few limitations that this research is prone to. Arguably, first, the cross-sectional design allows the finding of strong relationships but fails to determine causal relationships. Although it is fair to assume that EMCS reduces the incidence rates, one cannot ignore the fact that safer and more proactive hospitals are likely to have a predisposition towards the technologies. Second, the incident data were self-reported, which makes the results vulnerable to recall bias; this was partially addressed by adding to the departmental reports. Third, the investigation was only done among the large public tertiary care facilities in Riyadh; therefore, the results may not be generalizable to smaller facilities in other parts of the Kingdom that provide either private or primary care. Finally, the qualitative element, though full of knowledge, was based on a sub-sample of 35 participants, whose themes were saturated, and a projection to larger groups of people is to be done carefully. Altogether, this study confirms the idea that EMCS is an effective tool in improving safety in the workplace in healthcare facilities. However, they are deeply dependent on their holistic approach to implementation, which means the focus on human factors, thorough training, and organizational learning, along with the tech progress.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

CONCLUSION

The current research illustrates that the Electronic Monitoring and Control Systems (EMCS) implementation level at the Saudi Arabian health facilities is closely and significantly linked with a significant decrease in workplace accidents. The study was able to fulfill its aims through the quantification of a strong negative correlation between the scores of the EMCS and the occurrence rates, clarifying the staff perceptions that safety is improved, and defining the essential implementation obstacles, which are mostly insufficient training and lack of technical stability. The main conclusion is that the efficacy of EMCS cannot depend solely on technological presence, but it depends on the quality of integration and support on a critical basis. The main scientific value is a proven socio-technical model that proves superior system implementation as a direct predictor of reduced incident rates, even when accounting for departmental risk and staff experience. Although EMCS can be viewed as a powerful tool of occupational safety improvement, its effectiveness still depends on the ability to solve the human and organizational aspects. The next step in research should be to identify and implement specific intervention methods, e.g., standardized training regimes and enhanced system interoperability, to overcome the barriers identified and ensure the highest level of safety of these technologies in complex clinical settings.

REFERENCES

1. Alshammari, F. (2022). Needle Stick and Sharp Object Injuries (NSSIs) and Reporting Rates among Health Care Workers in the Hospitals of Northern Border Region (Saudi Arabia): A Cross Sectional Study (Master's thesis, Alfaisal University (Saudi Arabia)).
2. Tursunbayeva, A. (2019). Human resource technology disruptions and their implications for human resources management in healthcare organizations. BMC health services research, 19(1), 268.
3. Chandra, P., Sachan, N., & Kumar, A. Automation of Medical Devices with Embedded Systems. In Embedded Systems for Biomedical Applications (pp. 43-99). Chapman and Hall/CRC.
4. Philip Maurice, E. (2025). Incident Response for the Internet of Things (Doctoral dissertation, Universitätsbibliothek Regensburg).
5. Alotaibi, Y. K., & Federico, F. (2017). The impact of health information technology on patient safety. Saudi medical journal, 38(12), 1173.
6. Gallina, M., Testagrossa, M., & Provenzani, A. (2025). Unit dose drug dispensing systems in hospitals: a systematic review of medication error reduction and cost-effectiveness. European Journal of Hospital Pharmacy.
7. Li, S. A., Jeffs, L., Barwick, M., & Stevens, B. (2018). Organizational contextual features that influence the implementation of evidence-based practices across healthcare settings: a systematic integrative review. Systematic reviews, 7(1), 72.
8. Sgourou, E., Katsakiori, P., Goutsos, S., & Manatakis, E. (2010). Assessment of selected safety performance evaluation methods in regards to their conceptual, methodological and practical characteristics. Safety science, 48(8), 1019-1025.
9. Suleiman, A. K., & Ming, L. C. (2025). Transforming healthcare: Saudi Arabia's vision 2030 healthcare model. Journal of pharmaceutical policy and practice, 18(1), 2449051.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

10. Aljerian, N. A., Almasud, A. M., AlQahtani, A., Alyanbaawi, K. K., Almutairi, S. F., Alharbi, K. A., ... & Alabdulaali, M. K. (2025, September). Exploring a Systems-Based Model of Care for Effective Healthcare Transformation: A Narrative Review in Implementation Science of Saudi Arabia's Vision 2030 Experience. In Healthcare (Vol. 13, No. 19, p. 2453).
11. Alqahtani, F. M., Alqahtani, N. S., Algarni, F. S., Almuhaidib, I. A., Alessa, F., & Noman, M. A. (2024). Development of an educational program for occupational health and safety in Saudi Arabia. Journal of Engineering Research.
12. Mahammedi, C., Butt, T. E., & Al-Mhdawi, M. K. S. (2025). Emerging technologies in health and safety management: current perspectives and future prospects. Research Companion to Innovation in Construction, 300-321.
13. Orhierhor, M., Pringle, W., Halperin, D., Parsons, J., Halperin, S. A., & Bettinger, J. A. (2023). Lessons learned from the experiences and perspectives of frontline healthcare workers on the COVID-19 response: a qualitative descriptive study. BMC Health Services Research, 23(1), 1074.
14. Cimini, C. (2020). A roadmap for the integration of human workers and technology in the next generation manufacturing systems: a socio-technical perspective.
15. Altoaimy, L. (2017). Driving change, 140 characters@ a time: A corpus-assisted discourse analysis of the Twitter debates on the Saudi ban on women driving (Doctoral dissertation, Carleton University).
16. Alsadhan, B. (2015). Emergency early responders and EMS transition in Saudi Arabia: proposed model for system improvement (Doctoral dissertation, University of Pittsburgh).
17. O'Donovan, R., Ward, M., De Brún, A., & McAuliffe, E. (2019). Safety culture in health care teams: A narrative review of the literature. Journal of nursing management, 27(5), 871-883.
18. Alyami, A. A. (2018). Smart e-health system for real-time tracking and monitoring of patients, staff and assets for healthcare decision support in Saudi Arabia (Doctoral dissertation, Staffordshire University).
19. Mansour, S., & Nogues, S. (2022). Advantages of and barriers to crafting new technology in healthcare organizations: a qualitative study in the COVID-19 context. International Journal of Environmental Research and Public Health, 19(16), 9951.
20. McCarthy, E., DeViva, J. C., Southwick, S. M., & Pietrzak, R. H. (2022). Self-rated sleep quality predicts incident suicide ideation in US military veterans: results from a 7-year, nationally representative, prospective cohort study. Journal of sleep research, 31(1), e13447.
21. Blanco-Munoz, E. (2025). Human Factors and Safety Culture: How Leaders Can Influence Behaviours for Good. CRC Press.
22. Lazányi, K. (2024, November). Are There Still Holes in the Swiss Cheese?—Exploring the Inherent Limits of Safety and the Human Factor. In International Conference on Central European Infrastructure Protection (pp. 17-30). Cham: Springer Nature Switzerland.
23. Ghatge, V. A., Kleihorst, R., & Pissoort, D. (2023). Ensuring Safety and Effectiveness of Medical Devices in the Presence of Electromagnetic Disturbances through Unified EMC Assurance: A Compliance Pattern. Safe AI Systems.

Power System Technology
ISSN:1000-3673
Received: 16-08-2025 Revised: 05-09-2025 Accepted: 28-10-2025

24. Gamage, I., Malik, M., Andargoli, A., & Clavijo, R. C. (2025). Theorizing Lean as a Socio-Technical System: Examining the Reciprocal Interactions between Lean Social and Technical Subsystems. IEEE Transactions on Engineering Management.
25. Fischer, M., Safaeinili, N., Haverfield, M. C., Brown-Johnson, C. G., Zionts, D., & Zulman, D. M. (2021). Approach to human-centered, evidence-driven adaptive design (AHEAD) for health care interventions: a proposed framework. Journal of General Internal Medicine, 36(4), 1041-1048.
26. Tu, H. N., Shan, T. H., Wu, Y. C., Shen, P. H., Wu, T. Y., Lin, W. L., ... & Cheng, C. L. (2023). Reducing medication errors by adopting automatic dispensing cabinets in critical care units. Journal of medical systems, 47(1), 52.
27. Alharbi, M. F. (2025). Does Electronic Health Record Implementation Enhance Hospital Efficiency and Patient Outcomes? A Comprehensive Systematic Review. SAGE Open, 15(3), 21582440251359791.
28. Woldemariam, M. T., & Jimma, W. (2023). Adoption of electronic health record systems to enhance the quality of healthcare in low-income countries: a systematic review. BMJ Health & Care Informatics, 30(1), e100704.
29. Zhang, R., Shao, D., Huang, H., Zhang, Y., Lin, J., Wu, W., ... & Zhou, S. (2025). Dilemmas and strategies in the working experience of resident training nurses rotated in the intensive care unit: a qualitative study. BMC Nursing, 24(1), 1302.
30. Torous, J., Bucci, S., Bell, I. H., Kessing, L. V., Faurholt-Jepsen, M., Whelan, P., ... & Firth, J. (2021). The growing field of digital psychiatry: current evidence and the future of apps, social media, chatbots, and virtual reality. World psychiatry, 20(3), 318-335.
31. Chandra, P., Sachan, N., & Kumar, A. Automation of Medical Devices with Embedded Systems. In Embedded Systems for Biomedical Applications (pp. 43-99). Chapman and Hall/CRC.
32. Hong, Y., & Cho, J. (2023). Enhancing individual worker risk awareness: A location-based safety check system for real-time hazard warnings in work-zones. Buildings, 14(1), 90.
33. Ayaz, H., & Dehais, F. (2021). Neuroergonomics. Handbook of human factors and ergonomics, 816-841.
34. Nderitu, J. H. (2023). Mental State Adaptive Interfaces as a Remedy to the Issue of Long-term Continuous Human Machine Interaction. Journal of Robotics Spectrum, 1, 078-089.
35. Jørgensen, B. N., & Ma, Z. G. (2025). Digital Twin of the European Electricity Grid: A Review of Regulatory Barriers, Technological Challenges, and Economic Opportunities. Applied Sciences, 15(12), 6475.
36. Ștefan, A. M., Rusu, N. R., Ovreiu, E., & Ciuc, M. (2024). Empowering healthcare: A comprehensive guide to Implementing a robust medical information system—components, benefits, objectives, evaluation criteria, and seamless deployment strategies. Applied System Innovation, 7(3), 51.
37. Folse, V. N. (2022). Quality and safety. Leading and Managing in Nursing E Book. Canada: Elsevier, 18.