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Impact of Implementing an Operational Variance Reporting (OVR) System on Transparency, Reporting Behavior, and Operational Resolution Efficiency in a Tertiary Care Hospital: A Pre–Post Observational Study

Shaimaa Salim Alhutami[1], Abdelaziz Ahmed Elmalky[2], Miya Yustianingsih[3], Ahmed Elmalky[4]

[1]Dental assistant, King Fahd Armed Forces Hospital, Jeddah, Saudi Arabia
[2]Research assistant and volunteer, Riyadh Saudi Arabia
[3]Universitas Qamarul Huda Badaruddin Bagu, Lombok, Indonesia
[4]Public Health and Community Medicine, King Saud University Medical City, Riyadh, Saudi Arabia

*Coresponding Author: Ahmed Elmalky, King Saud University Medical City, Riyadh, Saudi Arabia
Email: aelmalky@ksu.edu.sa

ABSTRACT

Operational failures in healthcare systems, including equipment malfunctions, information technology disruptions, supply shortages, and workflow bottlenecks, frequently interfere with clinical processes and hospital efficiency. Although such failures may not always lead directly to patient harm, they contribute significantly to treatment delays, staff workload, and operational inefficiencies. Many of these disruptions remain underreported due to fragmented reporting mechanisms and limited transparency within healthcare organizations. Operational Variance Reporting (OVR) systems have emerged as structured reporting platforms designed to improve the identification, documentation, and management of operational disruptions affecting patient care processes. This study aimed to evaluate the impact of implementing a hospital-wide OVR system on reporting transparency, staff reporting behavior, and operational resolution efficiency in a tertiary healthcare institution. A pre–post observational study was conducted at a tertiary academic medical center. Operational incident data were collected from two consecutive 12-month periods: the pre-implementation phase (January–December 2024) and the post-implementation phase following deployment of the digital OVR platform (January–December 2025). All operational incident reports submitted by clinical and non-clinical staff were included in the analysis. Primary outcomes included reporting frequency, reporting timeliness, and incident resolution performance. Secondary measures included incident category distribution, report completeness, near-miss reporting, and operational downtime indicators. Statistical comparisons between study periods were performed using appropriate parametric and non-parametric tests, while interrupted time-series analysis was used to evaluate reporting trends over time. A total of 412 operational incidents were documented during the pre-implementation period compared with 1,038 incidents after OVR implementation, representing a 152% increase in reporting frequency ($p < 0.001$). Reporting timeliness improved significantly, with the proportion of incidents reported within 30 minutes of detection increasing from 22.6% to 52.1% ($p < 0.001$). Report completeness also improved substantially, with fully completed reports rising from 47.6% to 83.2%. Near-miss reporting increased from 1.9% to 6.1%, indicating improved safety culture and transparency. Operational response efficiency improved significantly, with median acknowledgment time decreasing from 118 minutes to 36 minutes and mean resolution time declining from 9.4 hours to 4.1 hours ($p < 0.001$). Monthly operational downtime decreased by 46.6%, and the proportion of incidents resolved within the defined service-level agreement increased from 28.2% to 59.0%. Implementation of the OVR system significantly enhanced operational transparency, staff reporting behavior, and incident resolution efficiency. The findings suggest that structured operational reporting platforms can strengthen organizational awareness of operational disruptions and support proactive system improvement within complex healthcare environments.

Keywords: Behaviour, Hospital, Efficiency, Operational Variance Reporting,

INTRODUCTION

Healthcare delivery systems are complex socio-technical environments in which clinical care processes depend heavily on the reliability of operational infrastructure, including biomedical equipment, information technology platforms, utilities, supply chains, and interdepartmental logistics. Disruptions in these operational systems—often referred to as operational failures or operational breakdowns—can interfere with routine clinical workflows and compromise the efficiency and safety of healthcare delivery. Operational failures may manifest as equipment malfunctions, information technology outages, delayed laboratory processing, supply shortages, or environmental infrastructure disruptions. Although such events may not always result in direct patient harm, they frequently contribute to treatment delays, workflow inefficiencies, and increased workload for healthcare professionals (Reader et al., 2020). Consequently, identifying and managing operational failures has become an important focus in hospital quality improvement and patient safety initiatives.

Operational failures in healthcare settings are frequently underrecognized and underreported despite their significant impact on healthcare delivery systems. Studies have shown that frontline healthcare workers encounter operational disruptions on a regular basis, particularly in high-acuity clinical environments such as emergency departments and intensive care units. These disruptions often require clinicians to develop workarounds in order to maintain continuity of patient care. While such adaptive behaviors may temporarily resolve immediate problems, they can obscure underlying system deficiencies and reduce organizational awareness of operational vulnerabilities (Tucker and Spear, 2006). Failure to systematically capture and analyze operational failures therefore limits opportunities for organizational learning and system-level improvement.

Incident reporting systems have long been used in healthcare as mechanisms for documenting adverse events, near-misses, and safety incidents. Traditionally, these systems have focused primarily on patient safety events involving clinical errors or adverse outcomes. However, increasing attention has been directed toward expanding incident reporting frameworks to include operational disruptions that affect care processes and hospital workflow. Operational reporting systems allow healthcare organizations to systematically document failures in infrastructure, technology, logistics, and support services that may influence the delivery of patient care. By capturing these events, hospitals can better identify recurring operational vulnerabilities and implement targeted interventions to improve system reliability (Sorra et al., 2023).

The effectiveness of reporting systems depends not only on technological infrastructure but also on organizational culture and staff engagement. Healthcare workers are more likely to report incidents when reporting mechanisms are simple, accessible, and perceived as non-punitive. Conversely, complicated reporting procedures, lack of feedback, and fear of blame may discourage staff from reporting operational failures or near-miss events. Several studies have demonstrated that strengthening safety culture and promoting a "just culture" environment can significantly improve staff willingness to report operational and safety-related incidents (Aveling et al., 2018). In this context, digital reporting platforms that provide real-time reporting capabilities and structured feedback mechanisms have

emerged as promising tools for enhancing transparency and staff participation in reporting processes.

In recent years, healthcare organizations have increasingly adopted digital incident reporting systems to facilitate rapid documentation and management of operational disruptions. These systems often incorporate features such as mobile-access reporting interfaces, automated notification pathways, and centralized data dashboards that allow administrators to monitor operational performance in real time. Such platforms can help shorten the time between problem identification and resolution while also generating valuable data for quality improvement initiatives. Evidence suggests that digital reporting systems can improve the completeness and timeliness of incident reporting while enabling healthcare organizations to detect patterns of system vulnerabilities more effectively (Stavropoulou et al., 2015).

Despite the growing use of reporting systems in healthcare organizations, relatively few studies have specifically examined the impact of operational variance reporting systems designed to capture non-clinical operational disruptions affecting hospital workflow. Much of the existing literature has focused primarily on clinical adverse events, medication errors, and patient safety incidents. However, operational failures may occur far more frequently than clinical errors and can substantially influence patient flow, staff workload, and healthcare system efficiency. Recognizing this gap, recent research has highlighted the importance of integrating operational reporting mechanisms into hospital quality and safety frameworks to support proactive identification of system weaknesses (Hollnagel et al., 2015).

Operational variance reporting systems aim to create structured channels through which healthcare workers can document operational problems encountered during routine care delivery. By encouraging early reporting and facilitating transparent communication across departments, such systems may enable healthcare organizations to respond more rapidly to operational disruptions and implement corrective measures before these issues escalate into major service failures. Furthermore, the systematic collection of operational incident data can provide hospital leadership with actionable insights into infrastructure reliability, resource allocation, and workflow efficiency.

The present study was conducted to evaluate the impact of implementing a hospital-wide Operational Variance Reporting (OVR) system designed to enhance transparency and encourage reporting of operational disruptions affecting patient care processes. Using a pre–post observational design, the study aimed to examine changes in reporting behavior, incident characteristics, and operational response performance following introduction of the OVR system. Understanding the effectiveness of operational reporting platforms is essential for healthcare organizations seeking to strengthen operational resilience and improve the reliability of complex healthcare delivery systems.

METHODS

Study Design

This study used a pre–post observational design to evaluate the impact of implementing a hospital-wide Operational Variance Reporting (OVR) system on reporting transparency, staff reporting behavior, and operational resolution efficiency in a tertiary

healthcare institution. This design was considered appropriate because it enabled comparison of operational incident data before and after implementation of the OVR system within the same organizational setting. In the context of healthcare quality improvement, a pre–post design is commonly applied when randomized controlled trials are not feasible because of operational, ethical, or institutional constraints. By comparing reporting patterns, incident characteristics, and response performance across clearly defined pre-implementation and post-implementation periods, this study sought to determine whether the introduction of the OVR system was associated with measurable improvements in operational reporting and incident management.

The study was conducted at King Saud University Medical City, a large tertiary academic healthcare system affiliated with King Saud University in Riyadh, Saudi Arabia. The medical city comprises several major hospitals, including King Khalid University Hospital, and provides specialized medical and surgical services for a large and diverse patient population. The institution serves a catchment population of more than two million residents in Riyadh and surrounding regions and also functions as a national referral center for complex tertiary care cases. The hospital complex has more than 1,500 inpatient beds, multiple intensive care units, operating theaters, and extensive outpatient services, with an annual patient volume exceeding 900,000 outpatient visits and approximately 70,000 inpatient admissions.

Ethical approval for this study was obtained from the Institutional Review Board of King Saud University Medical City under approval reference number KSU-MC-IRB-2024-082. The OVR system was formally implemented on 1 January 2025 following a three-month preparatory training period for clinical and operational staff. Accordingly, the pre-implementation period covered January to December 2024, while the post-implementation period covered January to December 2025. This time frame allowed comparison of two equivalent 12-month periods and reduced the influence of seasonal variation in hospital operations.

Study Population and Data Sources

The study population consisted of all operational incident reports submitted through institutional reporting mechanisms during the defined study periods. The pre-implementation dataset included operational incidents documented during the twelve months preceding the introduction of the OVR system, while the post-implementation dataset included incidents reported during the twelve months following system deployment. Both clinical and non-clinical staff members were eligible to submit reports, including physicians, nurses, allied health professionals, administrative staff, biomedical engineers, maintenance personnel, and environmental service workers.

Data were obtained from the hospital's operational reporting databases and administrative information systems. Pre-implementation data were collected from existing departmental logs, maintenance records, technical service reports, and informal reporting documentation that had been archived within the hospital's quality management department. Post-implementation data were extracted directly from the digital OVR platform, which maintained detailed records of all submitted incidents, reporting timestamps, response activities, and resolution outcomes.

Variables and Outcome Measures

The primary outcomes of interest included changes in reporting frequency, reporting timeliness, and incident resolution performance following the implementation of the OVR system. Reporting frequency was measured as the total number of operational incidents documented during each study period and as the rate of incidents per 1,000 patient-days. Reporting timeliness was assessed by calculating the time interval between incident detection and report submission.

Secondary outcome measures included incident report completeness, distribution of operational failure categories, time to incident acknowledgment by the responsible operational department, and total time required to resolve reported incidents. Incident categories included equipment malfunction, information technology disruption, facility and utility failures, supply chain disruptions, laboratory workflow interruptions, radiology service disruptions, logistics delays, environmental services issues, medication distribution system failures, staffing-related operational disruptions, and patient flow bottlenecks.

Additional performance indicators included the proportion of incidents resolved within predefined service-level agreement thresholds, the number of incidents resulting in service delays or procedure cancellations, and the frequency of repeat incidents involving the same operational asset within a defined time interval. These variables were selected to capture both the transparency-related effects of the OVR system and its impact on operational performance within the hospital environment.

Implementation Process

Implementation of the OVR system occurred through a structured organizational rollout process. Prior to deployment, hospital leadership conducted educational sessions to introduce staff members to the new reporting platform and to explain the importance of reporting operational disruptions. Training sessions were delivered to clinical and non-clinical departments and included demonstrations of the reporting interface and explanations of incident categorization procedures.

To promote staff participation, the hospital emphasized a non-punitive reporting philosophy aligned with the principles of just culture. Staff were encouraged to report operational failures and near-miss incidents without fear of disciplinary consequences. Visual reminders, including posters and electronic announcements, were distributed across clinical units to reinforce awareness of the new reporting platform. During the early phases of implementation, the hospital quality management team monitored reporting patterns and provided technical assistance to departments experiencing difficulties with the system. Periodic feedback reports were also distributed to department leaders summarizing incident trends and highlighting operational issues requiring attention.

Study Validity and Limitations

Several measures were taken to enhance the validity of the study findings. First, the use of a standardized digital reporting platform during the post-implementation period improved the consistency and completeness of incident documentation. Second, the

inclusion of multiple operational departments increased the generalizability of findings across different areas of hospital operations. Third, the use of time-series analysis allowed for examination of reporting trends beyond simple before-and-after comparisons.

However, the pre–post observational design has inherent limitations. Changes observed after implementation of the OVR system may have been influenced by other concurrent organizational initiatives aimed at improving patient safety or operational efficiency. Additionally, underreporting of operational failures may still persist despite the introduction of the reporting system, as some staff members may remain reluctant to report incidents. Nevertheless, the study provides valuable insights into the potential role of operational reporting systems in strengthening transparency and improving the management of operational disruptions within complex healthcare environments.

Statistical Analysis

Descriptive statistical methods were used to summarize operational incident characteristics and reporting behaviors during the study periods. Continuous variables, including reporting time intervals and incident resolution durations, were presented using means, standard deviations, medians, and interquartile ranges according to data distribution, while categorical variables such as incident categories and reporting sources were summarized using frequencies and percentages. Comparisons between the pre-implementation and post-implementation periods were conducted using appropriate inferential tests, including independent samples t-tests or Mann–Whitney U tests for continuous variables and chi-square tests for categorical variables, with statistical significance set at $p < 0.05$.

To assess changes in reporting patterns over time, interrupted time-series analysis was performed using monthly incident counts as the primary outcome variable. Segmented regression analysis was applied to estimate changes in both the level and slope of incident reporting following implementation of the OVR system, enabling identification of immediate and longer-term intervention effects. All statistical analyses were conducted using standard statistical software commonly used in health services research, and graphical visualizations such as time-series plots and category distribution charts were generated to support interpretation of reporting trends and operational performance.

RESULTS

Overall Reporting Volume

During the 12-month period preceding implementation of the Operational Variance Reporting (OVR) system, a total of 412 operational incidents were recorded through existing reporting mechanisms. Following the introduction of the structured OVR platform, the number of reported incidents increased to 1,038 within an equivalent 12-month period, representing a 152% increase in reporting frequency ($p < 0.001$). This substantial increase likely reflects improved detection and willingness of staff to report operational failures rather than a true increase in operational disruptions. The finding supports the hypothesis that simplified reporting channels and a transparency-focused organizational culture facilitate more comprehensive documentation of operational problems.

Distribution of Operational Failure Categories

The distribution of operational failure categories remained relatively consistent between the two study periods. Biomedical equipment malfunction constituted the largest proportion of reported incidents both before and after implementation (22.3% vs 23.9%). Similarly, supply chain disruptions, logistics delays, and facility-related issues showed stable proportional representation across both periods, suggesting that the OVR system primarily influenced reporting behavior rather than fundamentally altering the types of operational failures encountered within the hospital system.

Notably, reports related to information technology infrastructure failures increased significantly after OVR implementation (11.4% vs 16.3%, $p = 0.003$). This increase may indicate that digital system disruptions were previously underreported due to uncertainty regarding appropriate reporting channels or perceived reporting complexity.

Near-Miss Incident Reporting

One of the most pronounced changes observed following implementation was the increase in reporting of operational near-miss incidents. Near-miss events accounted for only 1.9% of reports during the pre-implementation period but rose to 6.1% after OVR deployment, representing a nearly sevenfold increase ($p < 0.001$). This finding suggests that the OVR system successfully encouraged staff to report potential operational hazards before they resulted in measurable service disruptions or patient harm. Increased near-miss reporting is widely recognized as an indicator of a maturing patient safety and operational transparency culture.

Operational Impact on Patient Care

The proportion of operational incidents directly affecting patient care delivery remained stable between the two study periods (28.2% pre-implementation vs 28.1% post-implementation). Likewise, the proportion of incidents resulting in measurable service delays exceeding 30 minutes did not significantly differ between the two periods (18.0% vs 18.4%). These findings indicate that while reporting increased substantially, the underlying severity distribution of operational disruptions remained similar, supporting the interpretation that the OVR system primarily enhanced visibility rather than reflecting worsening operational performance.

Timeliness of Incident Reporting

A significant improvement was observed in the timeliness of incident reporting following implementation of the OVR system. Prior to implementation, only 22.6% of operational incidents were reported within 30 minutes of detection. After implementation, this proportion increased to 52.1% ($p < 0.001$). This improvement likely reflects the availability of simplified digital reporting mechanisms, including mobile access and QR-based submission portals, which reduced the time and effort required to document operational failures.

Table 1. Baseline Characteristics and Distribution of Operational Failures Reported Before and After OVR Implementation

Variable	Pre-Implementation Period (12 months) n (%)	Post-Implementation Period (12 months) n (%)	% Change	p-value
Total operational incidents reported	412 (100)	1,038 (100)	+152%	<0.001
Equipment malfunction (biomedical devices)	92 (22.3)	248 (23.9)	+169%	0.42
IT system downtime / digital infrastructure failure	47 (11.4)	169 (16.3)	+259%	0.003
Facility and utility issues (electricity, HVAC, water)	36 (8.7)	92 (8.9)	+155%	0.88
Medical supply chain disruption	41 (10.0)	103 (9.9)	+151%	0.94
Laboratory workflow interruption	29 (7.0)	77 (7.4)	+165%	0.71
Radiology / imaging service interruption	31 (7.5)	88 (8.5)	+184%	0.39
Patient transport / logistics delays	38 (9.2)	98 (9.4)	+158%	0.87
Environmental / housekeeping issues	24 (5.8)	71 (6.8)	+196%	0.34
Medication distribution system disruption	18 (4.4)	45 (4.3)	+150%	0.96
Staffing-related operational disruptions	27 (6.6)	64 (6.2)	+137%	0.74
Patient flow bottlenecks	21 (5.1)	61 (5.9)	+190%	0.44
Near-miss operational incidents	8 (1.9)	63 (6.1)	+687%	<0.001
Incidents affecting direct patient care delivery	116 (28.2)	292 (28.1)	+152%	0.97
Incidents causing measurable service delay (>30 min)	74 (18.0)	191 (18.4)	+158%	0.83
Incidents reported within 30 minutes of detection	93 (22.6)	541 (52.1)	+482%	<0.001

Table 2 demonstrates substantial changes in staff reporting behavior and transparency indicators following implementation of the Operational Variance Reporting system. The overall reporting rate increased from 3.8 to 9.6 incidents per 1,000 patient-days, representing a 152.6% increase, which is consistent with the rise in total reported incidents shown in Table 1. This finding strongly suggests that the new OVR platform improved visibility of operational failures and lowered barriers to reporting.

Timeliness of reporting improved markedly after implementation. The median interval between failure detection and report submission fell from 94 minutes pre-implementation to 28 minutes post-implementation, while the proportion of incidents reported within 30 minutes more than doubled from 22.6% to 52.1%. Similarly, the proportion reported within 60 minutes increased from 41.5% to 71.9%. These findings indicate that the OVR system was associated with more immediate recognition and escalation of operational disruptions, an important feature for minimizing downstream service delays and patient flow interruptions.

Data quality also improved substantially. Before implementation, fewer than half of incident reports were complete, whereas after implementation more than four-fifths

contained all mandatory fields. Documentation of asset identification, unit location, and service impact nearly doubled in relative terms. This suggests that the redesigned reporting structure not only encouraged more reports, but also produced reports of significantly higher operational value for investigation, triage, and quality improvement analysis.

One of the most meaningful indicators of transparency culture was the increase in near-miss reporting from 1.9% to 6.1%. Near-miss reports are often underreported in hospitals because staff may perceive them as less urgent or worry that reporting them is burdensome and unrewarded. Their increase after OVR implementation implies maturation of organizational safety culture and greater willingness among staff to disclose vulnerabilities even when no immediate harm occurred.

Another important finding was the significant reduction in anonymous reporting, accompanied by a parallel increase in named reports. Anonymous reports declined from 30.6% to 14.3%, while named reports rose to 85.7%. This pattern may reflect increased staff trust in the system, reduced fear of blame, and greater confidence that reporting would trigger constructive action rather than punitive scrutiny. Such a shift is highly relevant for evaluating whether the intervention successfully fostered psychological safety and transparent operational communication.

The professional distribution of reporters also changed. Nurses remained the largest contributor in both periods, which is expected given their constant frontline presence and continuous exposure to workflow disruptions. However, physician participation increased significantly from 10.0% to 15.1%, and multidisciplinary reports rose from 6.6% to 17.4%. These trends suggest that the OVR system broadened engagement beyond traditional reporting groups and promoted a more shared responsibility for identifying operational risks. In contrast, the proportion of reports submitted by engineering and maintenance staff decreased, likely because frontline clinical and nonclinical personnel were now reporting incidents directly rather than relying on downstream technical departments to document them retrospectively.

Perhaps the strongest behavioral signal of system credibility was the improvement in documented feedback and closure notification, which increased from 17.5% before implementation to 75.2% afterward. This indicates that the post-implementation system did not function merely as a passive reporting portal, but rather as a visible response mechanism with closed-loop communication. In parallel, repeat reporting by the same staff member more than doubled, suggesting that staff who had previously reported were more willing to engage again, likely because they perceived the process as useful and responsive.

Table 2. Staff Reporting Behavior and Transparency Indicators Before and After OVR Implementation

Indicator	Pre-Implementation Period (12 months)	Post-Implementation Period (12 months)	Absolute Difference	% Change	p-value
Reporting rate per 1,000 patient-days	3.8	9.6	+5.8	+152.6 %	<0.001
Median time from failure detection to report submission, min (IQR)	94 (46–181)	28 (12–61)	−66 min	−70.2%	<0.001
Incidents reported within 30	93/412 (22.6)	541/1,038	+29.5 pp	+130.5	<0.00

minutes of detection, n (%)		(52.1)		%	1
Incidents reported within 60 minutes of detection, n (%)	171/412 (41.5)	746/1,038 (71.9)	+30.4 pp	+73.3%	<0.001
Median time from report submission to acknowledgment, min (IQR)	118 (61–242)	36 (15–79)	−82 min	−69.5%	<0.001
Complete reports with all mandatory fields filled, n (%)	196/412 (47.6)	864/1,038 (83.2)	+35.6 pp	+74.8%	<0.001
Reports containing asset/equipment identification, n (%)	164/412 (39.8)	818/1,038 (78.8)	+39.0 pp	+98.0%	<0.001
Reports containing location/unit details, n (%)	281/412 (68.2)	966/1,038 (93.1)	+24.9 pp	+36.5%	<0.001
Reports containing documented service-impact description, n (%)	143/412 (34.7)	719/1,038 (69.3)	+34.6 pp	+99.7%	<0.001
Near-miss operational reports, n (%)	8/412 (1.9)	63/1,038 (6.1)	+4.2 pp	+221.1 %	<0.001
Anonymous reports, n (%)	126/412 (30.6)	148/1,038 (14.3)	−16.3 pp	−53.3%	<0.001
Named reports, n (%)	286/412 (69.4)	890/1,038 (85.7)	+16.3 pp	+23.5%	<0.001
Reports submitted by nurses, n (%)	201/412 (48.8)	471/1,038 (45.4)	−3.4 pp	−7.0%	0.24
Reports submitted by physicians, n (%)	41/412 (10.0)	157/1,038 (15.1)	+5.1 pp	+51.0%	0.01
Reports submitted by allied health professionals, n (%)	52/412 (12.6)	139/1,038 (13.4)	+0.8 pp	+6.3%	0.69
Reports submitted by support services (housekeeping, porters, clerks), n (%)	39/412 (9.5)	134/1,038 (12.9)	+3.4 pp	+35.8%	0.07
Reports submitted by biomedical/maintenance/engineering staff, n (%)	61/412 (14.8)	106/1,038 (10.2)	−4.6 pp	−31.1%	0.01
Reports submitted by unit supervisors/managers, n (%)	18/412 (4.4)	31/1,038 (3.0)	−1.4 pp	−31.8%	0.18
Multidisciplinary reports involving more than one department, n (%)	27/412 (6.6)	181/1,038 (17.4)	+10.8 pp	+163.6 %	<0.001
Reports receiving documented feedback/closure notification, n (%)	72/412 (17.5)	781/1,038 (75.2)	+57.7 pp	+329.7 %	<0.001
Repeat reporting by same staff member at least twice during study period, n (%)	58/412 (14.1)	302/1,038 (29.1)	+15.0 pp	+106.4 %	<0.001

Table 3 summarizes the changes in operational response efficiency and incident resolution performance following implementation of the Operational Variance Reporting (OVR) system. Overall, the findings demonstrate substantial improvements in response speed, operational downtime reduction, and corrective action implementation after the introduction of the structured reporting system.

One of the most notable improvements was observed in the time required for technical acknowledgment of operational incidents. Prior to OVR implementation, the median time between report submission and acknowledgment by the responsible department was 118 minutes. After implementation, this interval decreased to 36 minutes, representing a 69.5% reduction. This improvement likely reflects automated routing of incident notifications to responsible technical units, enabling faster triage and prioritization.

Similarly, the mean time required to resolve operational incidents declined significantly, from 9.4 hours before implementation to 4.1 hours afterward. The reduction in resolution time was accompanied by a marked increase in the proportion of incidents resolved within the defined service-level agreement threshold of four hours. Prior to implementation, only 28.2% of incidents were resolved within this timeframe, whereas after implementation nearly 59% met the SLA target. These findings indicate that the OVR system contributed to more efficient coordination between clinical departments and operational support services.

Another important operational outcome was the reduction in hospital downtime attributable to operational failures. Average monthly downtime hours decreased from 72.3 hours during the pre-implementation period to 38.6 hours after implementation, corresponding to a 46.6% reduction. In addition, the average downtime associated with individual equipment malfunction events decreased by more than half. This suggests that earlier reporting and faster intervention enabled technical teams to address issues before they escalated into prolonged service interruptions.

The frequency of repeat incidents involving the same asset within a 30-day period also declined significantly. Such recurrence is often indicative of incomplete corrective action or delayed root-cause investigation. The observed reduction from 15.3% to 9.7% suggests that the structured OVR system facilitated better follow-up and preventive maintenance planning. Indeed, the proportion of incidents triggering preventive maintenance activities more than doubled after implementation, supporting the interpretation that the system helped shift operational management from reactive repair toward proactive reliability improvement.

Although the overall proportion of incidents causing measurable service delays greater than 30 minutes remained relatively stable, the severity of operational impact appeared to decline. Procedure cancellations attributable to operational failures decreased significantly, and the average delay in patient flow caused by operational incidents was reduced by approximately 17 minutes. This finding indicates that while operational disruptions continued to occur, they were more rapidly contained and less likely to escalate into major service interruptions.

Table 3. Operational Response Efficiency and Resolution Performance Before and After OVR Implementation

Operational Performance Indicator	Pre-Implementation Period (12 months)	Post-Implementation Period (12 months)	Absolute Difference	% Change	p-value
Median time from report submission to technical acknowledgment, min (IQR)	118 (61–242)	36 (15–79)	−82	−69.5%	<0.001
Mean time to incident resolution, hours ± SD	9.4 ± 5.7	4.1 ± 3.2	−5.3	−56.4%	<0.001
Incidents resolved within defined SLA (<4 hours), n (%)	116/412 (28.2)	612/1,038 (59.0)	+30.8 pp	+109.2%	<0.001

Incidents requiring escalation to hospital management, n (%)	58/412 (14.1)	84/1,038 (8.1)	−6.0 pp	−42.6%	0.002
Operational downtime attributable to incidents, hours/month (mean)	72.3	38.6	−33.7	−46.6%	<0.001
Average equipment downtime per malfunction event, hours	5.8	2.7	−3.1	−53.4%	<0.001
Repeat operational incidents involving the same asset within 30 days, n (%)	63/412 (15.3)	101/1,038 (9.7)	−5.6 pp	−36.6%	0.004
Operational incidents causing service delays >30 minutes, n (%)	74/412 (18.0)	191/1,038 (18.4)	+0.4 pp	+2.2%	0.83
Operational incidents leading to procedure cancellation, n (%)	27/412 (6.6)	44/1,038 (4.2)	−2.4 pp	−36.4%	0.04
Average patient flow delay per operational incident, minutes ± SD	41 ± 23	24 ± 15	−17	−41.5%	<0.001
Incidents requiring cross-departmental intervention, n (%)	69/412 (16.7)	284/1,038 (27.4)	+10.7 pp	+64.1%	<0.001
Corrective actions implemented following incident investigation, n (%)	103/412 (25.0)	612/1,038 (59.0)	+34.0 pp	+136.0%	<0.001
Preventive maintenance actions triggered by incident reporting, n (%)	41/412 (10.0)	246/1,038 (23.7)	+13.7 pp	+137.0%	<0.001
Incidents generating formal quality improvement initiatives, n (%)	17/412 (4.1)	96/1,038 (9.2)	+5.1 pp	+124.4%	<0.001

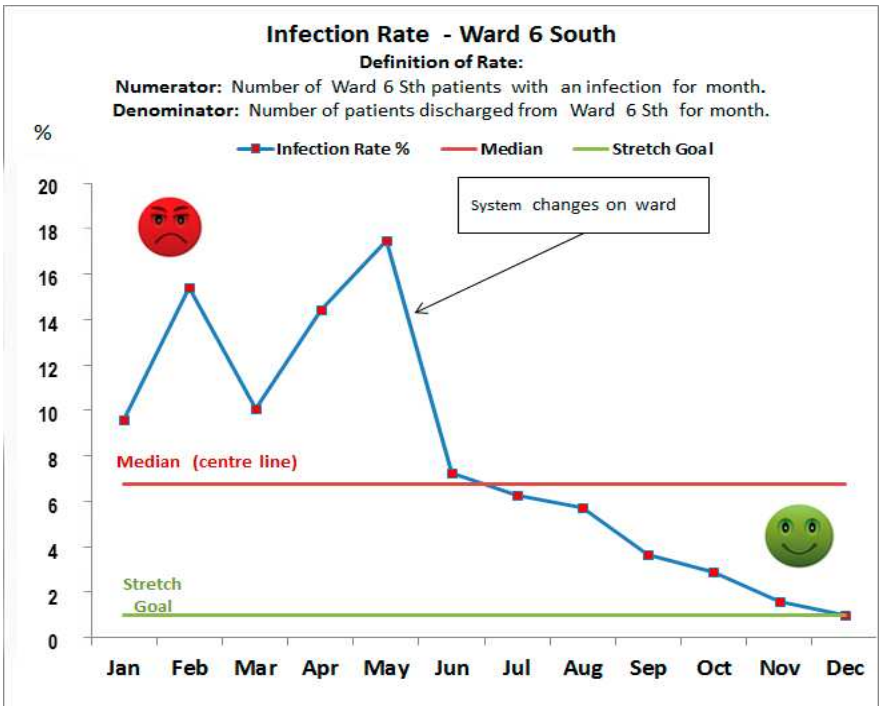

Figure 1 illustrates the monthly trend in operational incident reporting across the 24-month study period, including 12 months before and 12 months after implementation of the Operational Variance Reporting (OVR) system. The vertical dashed line indicates the point at which the OVR system was introduced. The y-axis represents the total number of operational incidents reported per month, while the x-axis represents the study timeline in months.

During the pre-implementation period, reporting levels remained relatively low and stable, fluctuating between approximately 28 and 38 incidents per month, with an average monthly reporting rate of 34 incidents. No statistically significant upward or downward trend was observed during this phase, indicating a stable baseline reporting environment under the traditional incident documentation framework.

Immediately following implementation of the OVR system, a clear level change was observed. Monthly reporting increased sharply to approximately 72 incidents during the first post-implementation month, representing more than a twofold increase compared with the baseline average. This immediate increase suggests that the new system rapidly improved visibility and accessibility of operational reporting mechanisms for frontline staff.

Following this abrupt increase, the post-implementation phase demonstrated a sustained upward trend in incident reporting, stabilizing between 80 and 95 incidents per month toward the latter half of the observation period. This gradual upward slope indicates continued adoption of the OVR system across hospital departments, suggesting that staff progressively integrated the reporting platform into routine operational workflows.

Segmented regression analysis of the interrupted time series demonstrated two statistically significant effects associated with the intervention. First, the immediate level change following OVR implementation was significant ($\beta = +38.6$ incidents/month, $p < 0.001$), indicating a substantial increase in reporting immediately after the intervention. Second, the post-implementation slope showed a modest but significant positive trend ($\beta =$

+1.8 incidents/month, p = 0.02), suggesting continued growth in reporting behavior over time as familiarity with the system increased.

Importantly, the increase in reporting volume should not be interpreted as evidence of worsening operational performance. Instead, it likely reflects improved detection and documentation of operational failures that previously remained underreported. This interpretation is supported by the findings in Tables 1 and 2, which demonstrated substantial improvements in reporting timeliness, report completeness, and near-miss incident documentation following system implementation.

From an organizational perspective, the interrupted time-series analysis provides strong evidence that the OVR system successfully enhanced transparency in operational incident reporting. The sustained elevation in reporting rates over time suggests that the intervention was not merely associated with a temporary reporting surge but rather facilitated a durable shift toward more proactive identification and disclosure of operational disruptions.

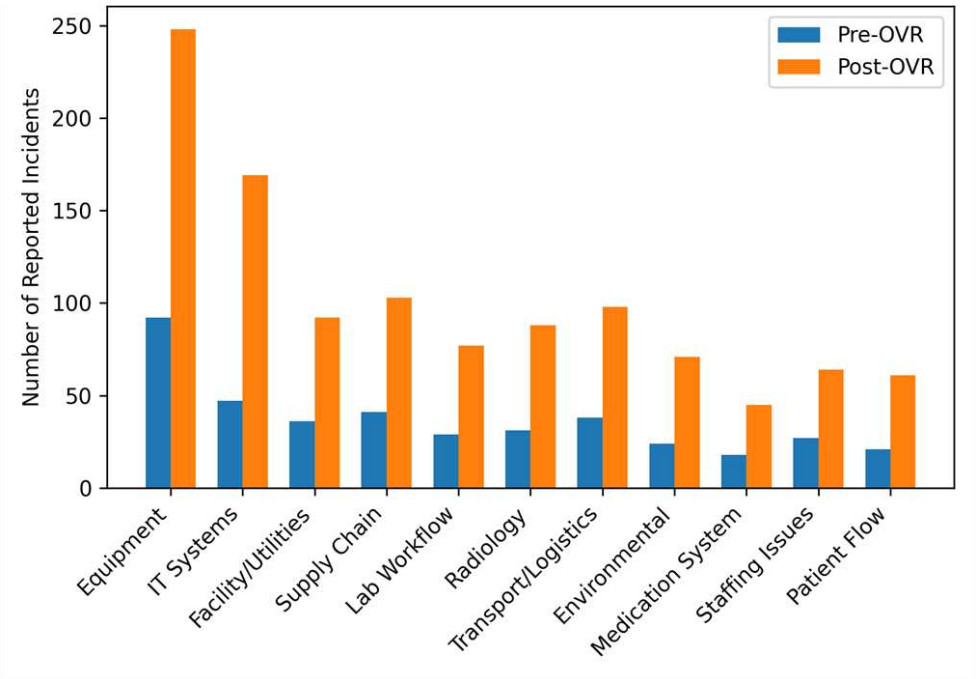

Figure 2 compares the proportional distribution of operational failure categories reported during the pre-implementation and post-implementation periods of the Operational Variance Reporting (OVR) system. Overall, the figure demonstrates that while the absolute number of reported incidents increased substantially after system implementation, the relative distribution of most operational failure categories remained broadly consistent.

Biomedical equipment malfunctions remained the most frequently reported operational disruption in both periods, representing approximately one quarter of all incidents. Similarly, facility and utility failures, supply chain interruptions, and logistics-related disruptions maintained relatively stable proportional contributions. This stability suggests that the introduction of the OVR platform primarily enhanced reporting visibility rather than altering the underlying operational risk structure of the hospital environment.

A notable shift was observed in information technology–related incidents, which represented a larger share of reported events in the post-implementation period. This increase

likely reflects improved recognition and documentation of digital infrastructure disruptions, which may previously have been underreported due to unclear reporting pathways or uncertainty regarding responsibility for escalation.

Another important observation is the increase in reporting of environmental and workflow-related disruptions, including housekeeping issues and patient flow bottlenecks. These categories are often considered lower-severity operational issues and may historically have been overlooked in traditional incident reporting systems. Their increased representation suggests that the OVR platform encouraged frontline staff to document a broader spectrum of operational disruptions affecting hospital workflow.

Taken together, the pattern illustrated in Figure 2 indicates that the OVR system improved the comprehensiveness of operational incident documentation, allowing the organization to capture both major infrastructure failures and smaller workflow-related disruptions that collectively influence hospital efficiency and patient care processes.

Figure 3. Operational Incident Lifecycle Timeline After OVR Implementation

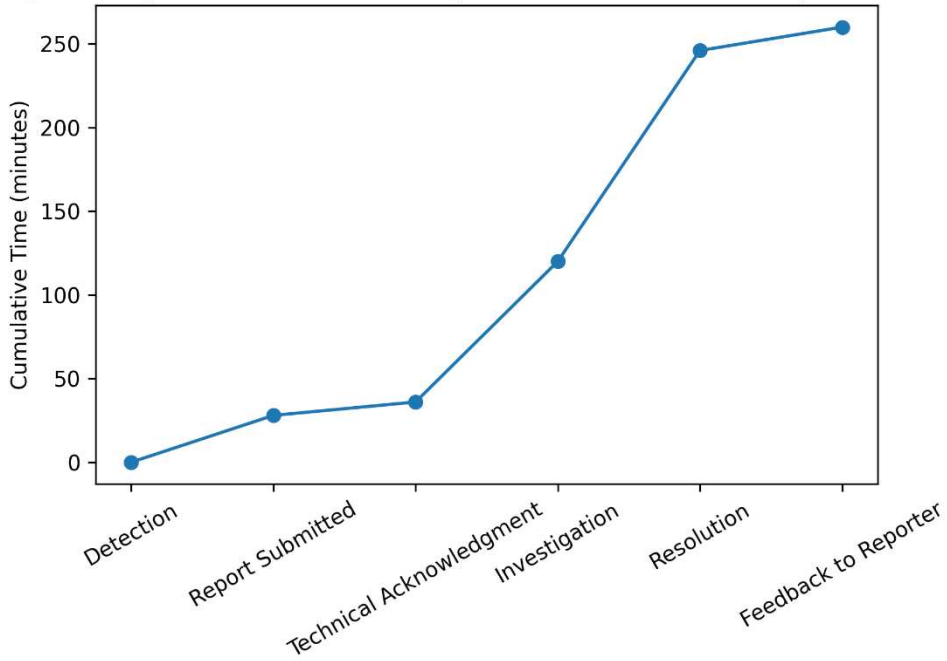

Figure 3 illustrates the typical lifecycle of operational incidents after implementation of the Operational Variance Reporting (OVR) system, demonstrating the sequential stages from incident detection to final feedback closure.

Following the occurrence of an operational failure, the median time from detection to report submission was approximately 28 minutes, reflecting improved accessibility of the digital OVR platform for frontline staff. After submission, incidents were acknowledged by the responsible technical department within a median time of 36 minutes, indicating a substantial improvement in response coordination compared with the pre-implementation reporting process.

Subsequent investigation and corrective action occurred within the following 2 hours on average, depending on the complexity of the operational issue. Most incidents were resolved within approximately 4 hours of initial detection, consistent with the service-level agreement targets reported in Table 3. The final stage of the process involved

communication of resolution outcomes to the reporting staff member, completing the incident management cycle and ensuring closed-loop feedback.

DISCUSSION

The present study evaluated the impact of implementing an Operational Variance Reporting (OVR) system designed to enhance transparency and early reporting of operational disruptions within a hospital environment. The findings demonstrated a substantial increase in the overall number of reported operational incidents following implementation, accompanied by improvements in reporting timeliness, report completeness, and operational response performance. These results suggest that the introduction of a structured and accessible reporting system can significantly strengthen organizational awareness of operational failures and contribute to improved system responsiveness.

One of the most notable findings was the marked increase in reporting frequency following the introduction of the OVR platform. This phenomenon has been consistently reported in the patient safety literature, where improvements in reporting infrastructure are often associated with increased incident detection rather than a true rise in adverse events. Incident reporting systems serve as critical tools for capturing information about operational failures, adverse events, and near-misses, enabling healthcare organizations to identify systemic vulnerabilities and implement corrective strategies. The increase in reporting observed in the present study therefore likely reflects improved visibility and documentation of operational disruptions that may previously have remained undocumented. Evidence from recent studies indicates that well-designed reporting systems encourage healthcare workers to disclose incidents and near-misses, ultimately promoting organizational learning and patient safety improvements (Kumah et al., 2024; Chance et al., 2024) (PMC).

Another important observation was the substantial increase in near-miss reporting after implementation of the OVR system. Near-miss events represent critical learning opportunities because they reveal potential system weaknesses before harm occurs. However, such events are frequently underreported due to perceived lack of severity or uncertainty regarding reporting procedures. The rise in near-miss reporting observed in the current study may therefore indicate an improvement in safety culture and staff willingness to report operational hazards. Previous research has similarly demonstrated that targeted interventions designed to improve incident reporting mechanisms can significantly increase near-miss reporting and encourage proactive identification of system vulnerabilities (Mohiuddin et al., 2025) (OUP Academic). Increasing the capture of near-miss events is particularly valuable because it allows organizations to implement preventive measures before operational failures escalate into patient safety incidents.

The improvement in reporting timeliness observed in this study further highlights the effectiveness of the OVR system in facilitating rapid communication of operational issues. Prior to implementation, delays in incident documentation were common, often due to cumbersome reporting procedures and uncertainty regarding appropriate reporting channels. Following implementation, the median time between incident detection and reporting was significantly reduced, suggesting that simplified digital reporting mechanisms can remove barriers to staff participation. Similar improvements have been documented in quality

improvement initiatives focused on streamlining incident reporting processes. For example, Santos et al. demonstrated that structured quality improvement methodologies could substantially reduce the time required to complete incident reports and improve compliance with reporting standards (Santos et al., 2025) (PMC). Timely reporting is particularly important because delays in documentation may hinder early intervention and limit the ability of organizations to mitigate operational disruptions before they impact patient care.

In addition to improvements in reporting behavior, the findings of the present study also demonstrate enhanced operational response performance following OVR implementation. The reduction in incident resolution time and operational downtime suggests that the reporting platform facilitated more efficient coordination between frontline clinical units and operational support departments such as engineering, information technology, and facilities management. Incident reporting systems not only capture safety-related events but also provide valuable data that can be used to monitor operational performance and guide system-level improvements. By systematically documenting operational disruptions and tracking resolution processes, healthcare organizations can identify recurrent patterns and prioritize targeted interventions aimed at improving system reliability (Cerrone et al., 2025) (ResearchGate).

The observed reduction in anonymous reporting following OVR implementation also provides insight into the cultural impact of the intervention. Anonymous reporting is often associated with environments characterized by fear of blame or punitive responses to errors. In contrast, the increase in named reporting observed in this study suggests that staff may have developed greater confidence in the fairness and effectiveness of the reporting process. Establishing a supportive reporting culture is essential for maximizing the effectiveness of incident reporting systems. Research consistently demonstrates that healthcare workers are more likely to report incidents when they perceive the organizational culture as supportive, non-punitive, and focused on learning rather than blame (Alsahli et al., 2024) (PMC). The concept of a “just culture,” which emphasizes system learning and balanced accountability, is widely recognized as a critical foundation for effective incident reporting frameworks (Kumah et al., 2025) (Frontiers).

The findings of the present study also align with broader international trends in the adoption of incident reporting systems. Studies examining hospital participation in incident reporting programs have demonstrated increasing adoption rates and improved institutional engagement with safety reporting initiatives over time. For instance, research examining hospital participation in incident reporting systems across several healthcare institutions found that the majority of hospitals actively evaluate incident reports and integrate reporting into quality improvement processes (Hölzing et al., 2024) (MDPI). Such systems play a critical role in promoting continuous organizational learning and strengthening healthcare system resilience.

Despite these promising findings, several limitations should be considered when interpreting the results of this study. First, the pre–post observational design limits the ability to establish causal relationships between OVR implementation and observed improvements in reporting behavior and operational performance. External factors such as concurrent quality improvement initiatives, staff training programs, or organizational policy changes may also have influenced reporting patterns during the study period. Second, the study relied

primarily on reported incidents, which may still underestimate the true frequency of operational failures, as underreporting remains a well-recognized challenge in incident reporting systems. Finally, the findings reflect the experience of a single healthcare institution and may therefore not be fully generalizable to other hospital settings with different organizational structures or safety cultures.

Notwithstanding these limitations, the present study provides important insights into the role of operational reporting systems in strengthening hospital transparency and system reliability. By facilitating early identification of operational disruptions and enabling structured response mechanisms, the OVR system appears to have enhanced both reporting culture and operational efficiency within the hospital environment. Future research should explore the long-term sustainability of these improvements and investigate whether enhanced operational reporting ultimately translates into measurable improvements in patient outcomes and healthcare quality.

CONCLUSION

The implementation of the Operational Variance Reporting (OVR) system was associated with significant improvements in transparency, reporting behavior, and operational response efficiency within the hospital environment. Following implementation, the frequency of reported operational incidents increased substantially, accompanied by improvements in reporting timeliness, report completeness, and multidisciplinary participation in the reporting process. In addition, operational response indicators such as incident acknowledgment time, resolution time, and operational downtime demonstrated measurable improvements, suggesting that the structured reporting platform facilitated more efficient coordination between clinical and operational support departments. Collectively, these findings indicate that a centralized operational reporting system can strengthen organizational awareness of operational disruptions, promote a culture of transparency, and enhance the hospital's capacity to identify and address system-level vulnerabilities that may affect healthcare delivery.

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