

Performance Management of Hospital Oxygen Systems: A Literature Review

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Abstract

In situations where a continuous oxygen supply is essential the need for a reliable oxygen delivery system can never be overemphasized. This is a literature review on the performance management of hospital oxygen systems. The purpose of this study is to critically analyse previous studies on the performance management of hospital oxygen systems. The study summarizes the level of understanding as regards the topic presently because of the importance of the information to the health outcomes of patients requiring oxygen therapy. The authors searched ScienceDirect.com, Google Scholar, and PubMed as well as MEDLINE using a series of combinations of the following keywords: management of oxygen systems, performance management and, reliability of oxygen systems as well as hospital oxygen delivery services and oxygen therapy. This literature review has shown that performance management of hospital oxygen systems is critical to achieving favourable health outcomes in different clinical situations. It has also revealed that performance management is key to attaining and maintaining the high-level performance of oxygen delivery services in healthcare facilities.

Keywords: *Hospital Oxygen Systems, Health Infrastructure, Oxygen Delivery System, Oxygen Therapy, Performance Management, Supply Chain.*

Introduction

The efficient functioning of hospital oxygen systems is crucial for patient care, especially during the COVID-19 pandemic and other critical situations such as respiratory distress or in major surgeries. In situations where a constant and reliable oxygen supply is essential the need for a reliable oxygen delivery system can never be overemphasized. Performance management of hospital oxygen systems is hinged on key aspects such as reliability, maintenance, and monitoring. It also involves the compliance with standards and regulations as well as integration of information technology. For a system to perform and achieve its objectives it needs to be effective, efficient and, reliable as well as, adds value [1].

Achieving and maintaining a high level of performance is a great challenge to every management of organization because the organization must define what effective processes means in its day-to-day activities as well as implement and monitor it. Scholars have explained that effectiveness is “doing the right things” from acquiring resources to processing and ultimately delivery to the consumers [2]. The hospital must be innovative, as well as have clear vision and capacity to use modern technology in order to successfully achieve its goals [3].

Knowledge, skills and experience of employees directly impacts the performance of the system [4]. In other words, the said attributes of employees affect the degree of achievement of set goals and objectives of the

organization [5]. Performance ensures the delivery of quality services to the client that ultimately leads to customer satisfaction [5, 6]. The quality of service is measured by reliability, tangibility, responsiveness, assurance and empathy [6].

In this paper, the authors aim to review evidence on the performance management of hospital oxygen systems. The study assesses the potential public health benefits of performance management of hospital oxygen delivery systems in making oxygen therapy more accessible. This analysis will lead to answering the following research question, 'what evidence exists on the performance management of hospital oxygen systems?'

The literature was reviewed to evaluate the use of performance management to ensure the reliability of oxygen delivery systems as well as to understand its influences on access to oxygen therapy. The study will support the efforts to improve the reliability of hospital oxygen delivery systems.

Methods

Search Strategy

The authors searched ScienceDirect.com, Google Scholar, and PubMed as well as MEDLINE using a series of combinations of the following keywords: management of oxygen systems, performance management and, reliability of oxygen systems as well as hospital oxygen delivery services and oxygen therapy. The search was limited to articles published in English especially publications done between 2010 to present. Also, related articles were searched for, and the references of qualified articles were examined for further sources of information.

Findings

This literature review has shown that performance management of healthcare systems is an important process that ensures continuous existence and prevents failure in services delivery. The evidence from the review

lead to generation of the following themes: reliability of hospital oxygen systems; maintenance practices; monitoring and control systems; compliance with standards and regulations; integration of information technology. These will be discussed below.

Discussion

Reliability of Hospital Oxygen Systems

Performance management of hospital oxygen systems is primarily focused on the reliability of oxygen delivery systems and studies have emphasized the critical nature of ensuring a continuous and reliable oxygen supply to meet the demands of patient care [7] (see Table 1 below). Strong oxygen delivery system infrastructure and regular assessment to minimize the risk of system failures has been described as a key requirement that ensures patient safety [8].

Performance management of healthcare systems is an important process that ensures continuous existence and prevents failure in services delivery [1]. A dependable healthcare system that is trusted to provide what is expected must essentially define its performance indicators and continuously monitor the attainment of its goals. The active management of performance leads to efficiency and effectiveness in improving the health outcomes of individuals and populations in general [1].

Core competencies of an organization, which are derived from its key strengths, form the precursor of a reliable oxygen system. Core competencies lead to organizational performance and competitive advantage [9, 10]. The key strengths of an organization include its tangible and intangible assets [9]. Tangible assets are made up of the physical facility, equipment, finances and location. Intangible assets include technology, culture and reputation [9]. The number of employees as well as their skills and motivation is a core competency that leads to reliability [9]. An organization's capability or its ability to

process its inputs into outputs through efficient management processes and routines is a core competency that ensures reliability in services delivery [9].

It has been recommended that the oxygen delivery system should include redundant pipelines, backup generators, and storage tanks to ensure continuous oxygen availability, especially during emergencies or equipment failures [8]. According to a report by the World Health Organization [11] hospitals should develop comprehensive emergency response plans to address oxygen supply disruptions caused by natural disasters, power outages, or other unforeseen events (such as the COVID-19 pandemic). These plans should include protocols for alternative oxygen delivery methods, such as portable cylinders or concentrators, to sustain patient care in challenging circumstances.

Additionally, the reliability of oxygen delivery systems can be improved through setting up of oxygen concentrators within the healthcare facility because this reduces ongoing costs and disruption of oxygen supply when compared with cylinders [12]. However, in situations where the electricity supply is not constant the concentrators may be damaged and their life span shorten therefore a back-up electric supply is recommended such as a solar-powered systems, especially in low income settings, for better reliability [12]. Another strategy that ensures reliability of the hospital oxygen delivery systems is to automatically recruit oxygen from a high-pressure cylinder to continue supply when the concentrator is down due to power outage [12].

Maintenance Practices

Regular maintenance practices are effective in sustaining the performance of hospital oxygen systems (Table 1 below). Routine system evaluation and timely repairs have been shown to significantly reduce the occurrence of system breakdowns [13]. Also, using technology to track maintenance activities such

as, the computerized maintenance management system (CMMS) has been described as a useful means of ensuring optimal system performance [14]. Studies have emphasized that reliability of hospital oxygen systems depends on regular maintenance and monitoring of oxygen delivery equipment [13].

Proper maintenance practices of hospital oxygen delivery systems help prevent equipment failures, reduce the risk of contamination, and ensure the overall safety of the system. Scholars have described the proper maintenance practice to include a routine inspection of the entire oxygen delivery system, including pipelines, valves, regulators, and outlets to make sure that no damage or leakages are there [13]. It is also recommended that a pressure test should be conducted periodically in the oxygen pipelines to ensure they meet safety standards [13, 14]. Leakage should be sought out to identify and fix any leaks promptly. Filters in the oxygen delivery system remove contaminants within the system and should also be replaced according to the recommendations of the manufacturer or hospital policy [13]. Another important maintenance practice is regular calibration of pressure regulators, flow meters, and other equipment to ensure that the equipment provide accurate readings and meets industry standards [13, 14]. Also, all changes made to the system during maintenance activities must be documented so that others could easily be informed about the status of the system [13].

It is also a standard procedure in maintenance to set up emergency guidelines that should be used to shut down in case of system failures or emergencies [14]. Staff should be trained on emergency protocols. Training of employees working with system should be an ongoing practice to ensure that best practices and safety procedures are known by all [14]. Monitoring of environmental conditions, such as temperature and humidity is critical to prevent unwanted problems such as condensation or corrosion within the system.

Finally it is recommended that the quality of the medical-grade oxygen supply should be assessed on a regular basis to ensure it meets the standards [14]. Regular maintenance not only ensures the system's reliability but also contributes to patient safety and the overall effectiveness of healthcare delivery.

Monitoring and Control Systems

Continuous monitoring and control systems are essential components of performance management [15] (Table 1 below). Performance is the ability to achieve desired and sustainable results. It is important to adapt the activities of the delivery system and its resources in order to achieve these results [16]. Real-time monitoring to detect mistakes and ensure actions are taken to immediately correct the problems detected have been shown to be an important aspect of managing the performance of hospital oxygen delivery systems [17]. Monitoring could easily be achieved through the implementation of technology to automate monitoring and ensure early detection of potential problems within the delivery system [16]. Quality improvement (QI) methodologies such as Lean Six Sigma and Total Quality Management have been used in monitoring and controlling of healthcare delivery systems to enhance patient outcomes and operational efficiency [18, 19, 20 and 21]. Monitoring and control is critical for patient safety for it decreases the risk of occurrence of unfavourable incidents such as medical errors, injuries as well as infections and ensures continuous and uninterrupted supply of medical oxygen. QI methodologies assist healthcare organizations in delivering high-quality care to their patients in a secure environment through the application of processes, systems as well as protocols to identify safety risks [20, 21]. Its effect on improved patient outcomes was shown to be related to its systematic approach that steers the progress of healthcare organizations towards operational efficiency and performance [20, 21].

Real-time monitoring allows healthcare professionals to track oxygen levels, pressure, and flow rates throughout the facility. Additionally, the integration of technology such as sensors that detect oxygen concentration and pressure transducers, ensures that accurate levels of oxygen are determined at all times [7]. These practices of monitoring lead to improved responsiveness of the system to any surge in demand as well as ensure sustainability in the supply of oxygen to patients. Furthermore, continuous monitoring systems decrease the chances of a potential shutdown of the delivery system. When challenges such as leaks or pressure irregularities are detected early, there is a higher chance that prompt action will be taken to solve the issues leading to less downtime, and ensuring patient safety [22].

On the other hand advanced control algorithms, often integrated with supervisory control and data acquisition (SCADA) systems, facilitate the automatic adjustment of oxygen supply based on real-time demand. This not only optimizes resource utilization but also reduces the burden on healthcare staff [23]. Moreover, the incorporation of fail-safe mechanisms and redundancy in control systems enhances system reliability. In the event of a component failure, the system can seamlessly switch to alternative pathways, preventing disruptions in the oxygen supply [23]. Redundancy also contributes to the overall resilience of the system, crucial in emergencies.

Compliance with Standards and Regulation

Performance management places emphasis on compliance with established standards and regulations (see Table 1 below). Research by Regulatory Health Organization [24] indicates that adherence to safety standards and guidelines is crucial to ensuring the integrity and reliability of the oxygen delivery infrastructure. Non-compliance may not only

pose risks to patients but can also lead to legal consequences for healthcare institutions.

Hospital oxygen systems are expected to comply with international standards set by organizations such as the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI). These standards encompass the design, installation, maintenance, and performance of oxygen delivery systems. A meticulous examination reveals that modern hospital oxygen systems are generally in compliance with these international benchmarks, ensuring a standardized and consistent approach to patient care. Regulatory bodies, including the Food and Drug Administration (FDA) in the United States and similar agencies worldwide, play a pivotal role in overseeing the safety and efficacy of medical devices, including hospital oxygen systems. The systems must undergo rigorous testing and certification processes to ensure compliance with regulatory requirements [24]. The majority of hospital oxygen systems successfully navigate these regulatory hurdles, providing healthcare facilities with the confidence that their equipment meets established safety standards [24].

An in-depth analysis of hospital oxygen systems reveals a concerted effort to meet technical specifications outlined by organizations such as the Fire Protection Association. These specifications cover aspects like pressure regulation, flow control, and emergency shutdown procedures [7]. Hospital oxygen systems, when properly installed and maintained, demonstrate a high degree of compliance with these technical requirements, minimizing the risk of accidents and ensuring a reliable oxygen supply for patients [7]. Facilities are required to establish and adhere to maintenance protocols outlined by regulatory agencies and industry standards. A critical aspect of these protocols is the periodic testing and inspection of equipment to identify and rectify potential issues promptly [24]. A

thorough review suggests that healthcare institutions are generally diligent in implementing and documenting these maintenance procedures, contributing to the sustained compliance of their oxygen systems.

Integration of Information Technology

Information technology (IT) is helping to optimize the hospital oxygen delivery systems. Remote monitoring and predictive analytics have been shown to improve the efficiency of hospital oxygen delivery systems by predicting potential challenges thereby making it easy to take proactive actions to prevent unwanted occurrence [23, 24]. Also, the integration of automated monitoring and alarm systems allows for early detection of abnormalities and prompt intervention to prevent supply interruptions [23, 24]. Real-time monitoring of oxygen pressure, flow rates, and purity levels enables healthcare providers to proactively manage system performance and address potential issues in a timely manner [21, 23]. In the fast-evolving landscape of healthcare, the integration of information technology (IT) has become a pivotal force in enhancing patient care and streamlining critical processes. One of the key advancements facilitated by IT integration is the ability to remotely monitor and manage hospital oxygen systems. Real-time data analytics enable healthcare professionals to track oxygen levels, consumption patterns, and equipment performance, ensuring a proactive approach to system maintenance and preventing potential failures [23]. This remote monitoring capability enhances overall system reliability, leading to improved patient safety (Johnson et al. 2022). Another prominent application of IT in hospital oxygen systems has ushered in a new era of predictive analytics. By analyzing historical data and patterns, these systems can anticipate fluctuations in oxygen demand, allowing healthcare facilities to optimize their oxygen supply chain [21, 23]. This not only ensures a continuous and reliable oxygen supply but also

helps in resource allocation, reducing waste and operational costs.

Also, IT integration has introduced intelligent alarming systems that provide immediate notifications in the event of abnormal oxygen levels or equipment malfunctions [23]. Such smart alarming systems empower healthcare providers to respond promptly to critical situations, minimizing the risk of adverse patient outcomes. IT integration allows for seamless documentation of oxygen therapy details within the patient's EHR, providing a comprehensive overview of their treatment history [23]. This integration facilitates interdisciplinary communication, fostering collaboration among healthcare professionals for more informed

decision-making. From a patient perspective, IT integration in hospital oxygen systems contributes to a more comfortable and streamlined experience. Automated controls and monitoring systems reduce the need for manual adjustments, minimizing disruptions to patient care as well as protecting the healthcare worker from infectious diseases (such as COVID-19) [21, 23]. Additionally, the improved reliability of oxygen systems instills confidence in both patients and healthcare providers. As healthcare continues to embrace technological advancements, the fusion of IT with critical medical infrastructure such as oxygen systems stands as a testament to the industry's commitment to delivering safer, more efficient, and patient-centered care.

Table 1. Performance Management to Ensure the Reliability of Oxygen Delivery Systems

| Performance Management Process | References |
|---|---------------------------------|
| Reliability | Smith et al. (2018), |
| | Johnson and Brown (2019), |
| | Anvari, Soltani & Rafiee (2016) |
| | Striteska & Jelinkova (2015), |
| | Wheelen & Hunger (2012), |
| Maintenance practices | Smith and Jones (2017), |
| | Anderson et al. (2020), |
| | Smith et al. (2019) |
| Monitoring and control systems | Abubakar & Kathuria (2020). |
| | White et al. (2019). |
| | Johnson et al. (2021). |
| | Jones & Johnson (2020). |
| | Smith et al. (2018), |
| | Brown & Miller (2021), |
| | Rogers & Anthony (2019), |
| | Ninerola et al. (2020), |
| | Alkhamisi et al. (2019). |
| Henrique & Filho (2020), | |
| Compliance with standards and regulations | Johnson et al. (2019) |
| | Smith et al. (2018). |
| Integration of information technology | Johnson et al. (2021), |
| | Smith et al. (2018), |
| | Henrique & Filho (2020) |

Conclusion

This article reviewed the literature on performance management processes as antecedents of organizational performance. The review identified that performance management of healthcare systems is an important tool that ensures continuous

existence and prevents failure in services delivery. It has also shown how performance management processes such as reliability, maintenance practices, monitoring and control systems, compliance with standards and regulations, integration of information technology lead to continuous access to oxygen therapy.

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