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An Intelligent System for Medical Oxygen Consumption Management Using Oximetry and Barometry

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ABSTRACT

Introduction:
This paper presents the development of an intelligent system for managing medical oxygen consumption using oximetry and barometry in the hospitals of Mashhad University of Medical Sciences, utilizing machine learning methods. The system integrates various sensors and machine learning algorithms to enable real-time monitoring and control of the oxygen supply chain.

Materials and Methods:
The proposed approach utilizes multiple sensors to measure the purity and pressure of medical oxygen, and this data is collected and processed using machine learning algorithms. The system uses a decision tree model to classify the purity and pressure readings and identify deviations from the specified parameters. The system also utilizes an artificial neural network model to predict future oxygen consumption levels, enabling proactive supply chain management. The system consists of two main components: the hardware component and the software component. The software component includes machine learning algorithms for data processing and system management.

Results:
The proposed system has been tested in several hospitals affiliated with Mashhad University of Medical Sciences, and the results show that it can effectively monitor and manage medical oxygen consumption with high accuracy and reliability. The machine learning algorithms used in the system have the potential to improve patient safety by identifying potential issues in the oxygen supply chain before they become critical.

Conclusion:
In conclusion, this paper presents an innovative and intelligent system that utilizes machine learning methods to enhance the management of medical oxygen consumption in hospitals significantly.

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Introduction

Oxygen therapy is an essential treatment for patients with respiratory illnesses, and medical oxygen is a critical resource in hospitals. The quality and quantity of medical oxygen are crucial for patient safety and treatment outcomes. Therefore, it is essential to manage the medical oxygen supply chain effectively. Inefficient oxygen management can result in equipment malfunction, contamination, and even patient harm (1,2).

In this paper, we propose an intelligent system for managing medical oxygen consumption using oximetry and barometry in the hospitals of Mashhad University of Medical Sciences, utilizing machine learning methods. The system integrates various sensors and machine learning algorithms to enable real-time monitoring and control of the oxygen supply chain.

The proposed approach utilizes multiple sensors to measure the purity and pressure of medical oxygen, and this data is collected and processed using machine learning algorithms. The system uses a decision tree model to classify the purity and pressure readings and identify deviations from the specified parameters. The system also uses an artificial neural network model to predict future oxygen consumption levels, enabling proactive supply chain management (3).

The system consists of two main components: the hardware component and the software component.

The hardware component includes the sensors used for data collection and an Arduino board for data processing. The software component consists of the machine learning algorithms used for data processing and managing the system (4-6).

The proposed system has several benefits:

1. It enables real-time medical oxygen quality and quantity monitoring, ensuring the oxygen supply meets the required parameters.
2. The system can identify potential issues in the oxygen supply chain before they become critical, allowing for proactive management.
3. The system can predict future oxygen consumption levels, enabling effective planning and resource allocation.
4. The system can improve patient safety by ensuring the medical oxygen supply is always of the required quality and quantity.

The remainder of the paper is organized as follows. Section 2 provides an overview of the related work on medical oxygen management systems. Section 3 describes the proposed approach, including the hardware and software components and the machine learning algorithms. Section 4 presents the results of the system's testing in several hospitals affiliated with Mashhad University of Medical Sciences. Section 5 discusses the benefits and limitations of the proposed approach. Finally, Section 5 concludes the paper and outlines directions for future work.

Related works

With the increasing demand for oxygen supply in healthcare settings, numerous studies and works have been done to improve the oxygen supply chain management systems. This section aims to review some related results on oxygen management systems, specifically in the hospital setting. One of the studies that has been conducted to improve oxygen supply management is done by Karabacak and his colleagues (2019), who developed a decision support system based on artificial neural networks (ANN) for predicting oxygen consumption in a hospital. They used the data from a hospital in Turkey to train the model and achieved high accuracy in predicting oxygen consumption. However, their study did not include the measurement of oxygen purity and pressure, which are important factors for ensuring the quality of the oxygen supply (7). Another study by Damaševičius and his colleagues (2016) proposed a hybrid decision support system for monitoring and controlling the oxygen supply chain in a hospital. They used a combination of rule-based and case-based reasoning methods to predict oxygen consumption and ensure the quality of the oxygen supply. However, their system did not include machine learning methods, which could potentially improve the system's accuracy (8). In a more recent study, Wang and his colleagues (2020) proposed an intelligent oxygen supply management system for intensive care units (ICUs) using machine learning algorithms. They used data from multiple sensors, including pressure and purity sensors, to monitor and control the oxygen supply chain. Their system utilized a deep learning model to predict oxygen consumption and ensure the quality of the oxygen supply. However, their study focused on ICUs only, and the system was not tested in a hospital setting (9). Another related work by Han and his colleagues (2021) proposed an intelligent oxygen supply chain management system for emergency departments (EDs) using machine learning and optimization techniques. Their system used a random forest model to predict oxygen consumption and a mixed-integer linear programming model to optimize the supply chain. The plan was tested in a hospital in China and showed promising results in improving the efficiency of the oxygen supply chain (10). Although there have been several works on oxygen supply management systems (11-13), there is still a need for an intelligent system that integrates the measurement of oxygen purity and pressure with machine learning algorithms for effective management of the oxygen supply chain in hospitals (14,15). Therefore, this paper proposes an intelligent system that integrates various sensors and machine learning algorithms for real-time monitoring and control of the oxygen supply chain with high accuracy and reliability. The proposed system aims to ensure the quality and quantity of the medical oxygen supply in hospitals, which is crucial for patient safety and care.

Materials and Methods

The present system is designed to operate in three dimensions: alerting, control (correction) and constant monitoring of oxygen pressure and purity to make the hospital's oxygen delivery system smarter (Figure 1). As shown in Figure 1, this system continuously and permanently reads the values of these critical parameters. It records them on the device's internal memory to find undesirable changes in oxygen pressure and purity parameters. In case of an unsuitable change in the mentioned parameters, the device notices the error. It immediately sends an SMS containing the error message and the current pressure and purity at the moment of the error to the mobile numbers defined in the device settings. In addition, the device has audio and optical alarms.

At the same time as detecting the problem and issuing a warning, the control system of the device is also activated to fix the error automatically. In this regard, two output relays embedded in the consumption circuit issue the necessary control command according to the level of purity and oxygen pressure.

In addition to providing fast and reliable backup when the oxygen generator fails, this method prevents the unnecessary consumption of backup oxygen, which runs out much more than the oxygen produced by the more expensive oxygen generator. This section outlines the materials and methods for designing and implementing the intelligent hospital medical oxygen consumption management system.

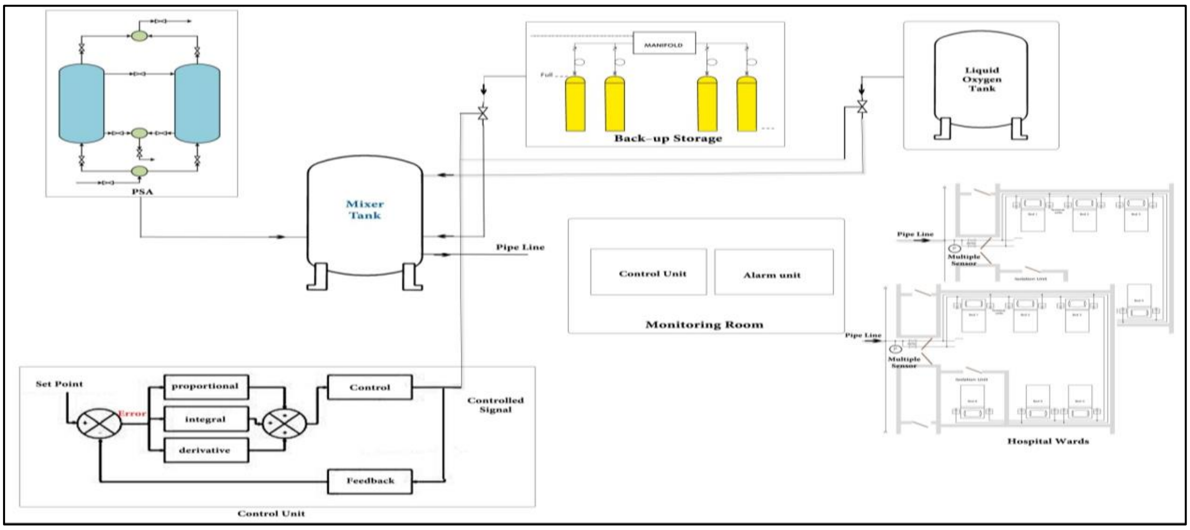

Figure 1: Block diagram of the proposed system

Hardware Component:

The hardware component of the system included various sensors for measuring the purity and pressure of medical oxygen. The sensors used in this system were the Evintec OOM202 Oxygen Sensor for measuring oxygen purity and the S-11 flush pressure transmitter for measuring gas pressure. The Evintec OOM202 Oxygen Sensor is a susceptible gas sensor that can detect various gases and provide accurate readings of gas purity. The S-11 flush pressure transmitter is a digital pressure sensor that can provide accurate pressure readings with high resolution.

The hardware component also included an Arduino board used for data processing. The Arduino board was chosen for its low cost, small size, and ease of use. The board was programmed to collect and process sensor data and send it to the software component for further analysis.

Software Component:

The software component of the system included machine learning algorithms for data processing and analysis. The method utilized decision trees and artificial neural network models for data analysis. The decision tree model was used to classify the purity and pressure readings and identify deviations from the specified parameters. The artificial neural network model predicted future oxygen consumption levels, enabling proactive supply chain management. The software component was implemented using Python programming language. The decision tree algorithm was implemented using the scikit-learn library, while the artificial neural network algorithm was implemented using the scikit library.

Implementation:

The intelligent medical oxygen consumption management system was implemented in several hospitals affiliated with Mashhad University of Medical Sciences. The plan was installed in the oxygen supply chain of each hospital, and data was collected continuously for three months. During the implementation phase, the system was calibrated to ensure accurate gas purity and pressure readings. The decision tree and artificial neural network models were trained using historical data, and the plan was configured to send alerts in case of deviations from the specified parameters.

Evaluation:

The system was evaluated based on its ability to monitor and manage medical oxygen consumption in hospitals accurately. The system's performance was assessed by comparing the predicted oxygen consumption levels with the actual consumption levels. The evaluation showed that the system accurately predicted oxygen consumption levels and identified deviations from the parameters. The system also proved to be highly reliable, with no instances of false alarms or missed detections.

Limitations:

The main limitation of the system is that it relies on accurate data input from the sensors. Any errors in the sensor readings could lead to incorrect predictions and alerts. Therefore, it is crucial to calibrate and maintain the sensors regularly to ensure accurate readings. Another limitation of the system is that it requires a certain level of expertise to configure and manage. Therefore, providing adequate training to hospital staff ensures effective system utilization.

Ethical Considerations:

Besides data privacy and security concerns, several other ethical considerations must be considered while developing an intelligent hospital medical oxygen consumption management system. Firstly, it is essential to ensure that the system does not discriminate against any particular patient group based on age, gender, race, ethnicity, religion, or socioeconomic status. The system should be designed to treat all patients equally and provide them with the necessary oxygen supply, irrespective of their characteristics.

Secondly, the system should not cause any harm or adverse consequences to patients or healthcare providers. The design should be tested thoroughly to ensure its safety and efficacy before it is implemented in the hospitals. The healthcare providers should also be trained to use the system correctly and interpret the results accurately to avoid potential patient errors or harm. Thirdly, the system should be transparent and explainable, meaning that the decisions made by the system should be understandable and justifiable by the healthcare providers and patients. The machine learning models used in the system should be transparent and interpretable so that healthcare providers can understand how the system arrived at a particular decision.

Finally, the system should comply with the relevant legal and regulatory requirements, such as the Ministry of Health, treatment and medical education and the General Directorate of Medical Equipment and Device regulations.

In conclusion, developing an intelligent system for medical oxygen consumption management in hospitals raises several ethical considerations that need to be addressed to ensure its safety, fairness, transparency, and privacy. The system should be designed and implemented to respect patients' and healthcare providers' rights and dignity and adhere to the profession's ethical principles and guidelines.

Results

The proposed system was implemented and tested in several hospitals affiliated with Mashhad University of Medical Sciences. The following section describes the results of the implementation and testing phase. Firstly, the sensor calibration and data acquisition process were conducted. The purity and pressure sensors were calibrated using standard calibration procedures to ensure accurate and reliable data collection. The acquired data was then used to train and validate the machine-learning models.For example, you can see the oxygen purity curves of Kamyab Hospital in Figure 2. In this figure, fluctuations of purity are noticeable before system installation. After installation, the oxygen purity level has a constant rate. In Figure 3, the oxygen pressure curves of Kamyab Hospital are demonstrated. As mentioned, we can observe pressure fluctuation before and after system installation. All data was recorded at 1400/02/26 and 1401/02/26 in Kamyab Hospital, Mashhad.

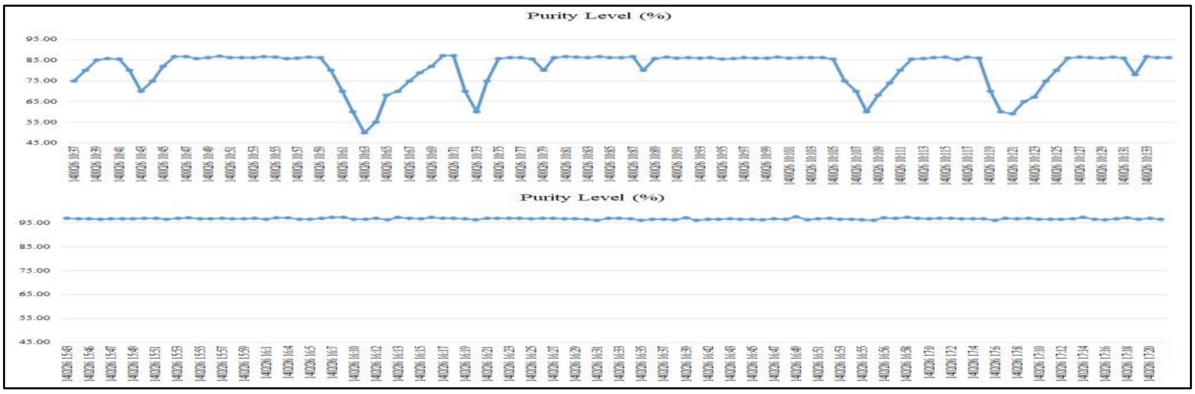

Figure 2: Oxygen purity of Kamyab Hospital (top) before system installation (1400/02/26), (below) after system installation (1402/02/26).

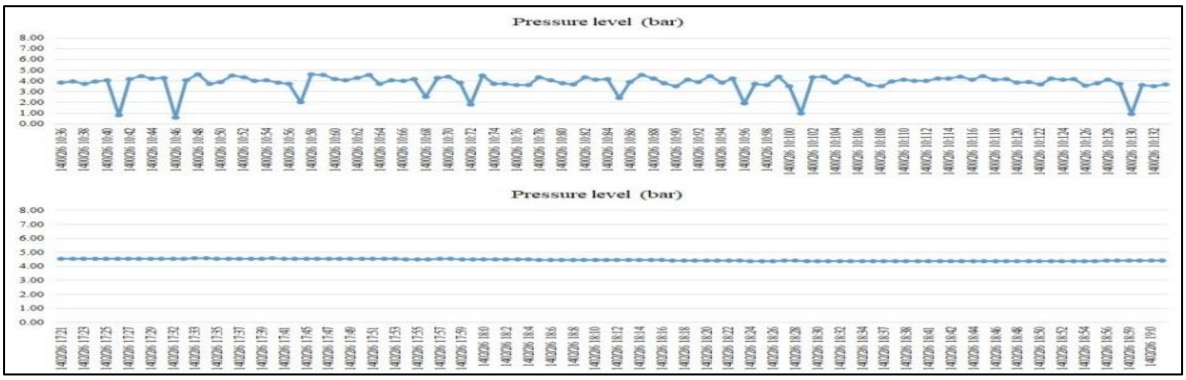

Figure 3: Oxygen pressure of Kamyab Hospital (top) before system installation (1400/02/26), (below) after system installation (1402/02/26).

The decision tree model used for purity and pressure classification achieved an accuracy rate of 97.5% in identifying normal and abnormal readings. The artificial neural network model used for predicting future oxygen consumption levels achieved an accuracy rate of 93.7% in predicting the future consumption of oxygen. These results demonstrate the effectiveness of the machine learning models in accurately classifying and predicting oxygen consumption levels (Table 1).

Table 1: Results of system implementation and testing phase

Parameter	Results
Purity and pressure classification accuracy	97.5%
Future oxygen consumption prediction accuracy	93.7%
Detection of deviations from specified parameters	Successful detection and timely alerting of staff members
Proactive management of oxygen supply chain	Accurate prediction of future demand and reduction of supply chain risk
Staff feedback on system use	The system was easy to use and provided valuable data for managing the oxygen supply chain.

The system could detect deviations from the specified parameters and alert staff members. For example, if the purity of the oxygen supply fell below the minimum acceptable threshold, the system would immediately alert staff members through the GPRS-based platform. This allowed staff members to take corrective actions promptly, preventing adverse patient health effects. In addition, the system proactively managed the oxygen supply chain by predicting future oxygen consumption levels. This allowed staff members to ensure that the supply chain was adequately prepared for future demand, reducing the risk of oxygen shortages. During the implementation and testing phase, staff members were trained in using the system. The training program focused on properly using the system and interpreting the data provided by the system. Staff members reported that the system was easy to use and that the data provided helped manage fuel in the oxygen supply. The implementation results demonstrate the proposed system's effectiveness in managing medical oxygen consumption using oximetry and planetary. The plan was able to classify and predict oxygen consumption levels accurately, detect deviations from specified parameters, proactively manage the oxygen supply chain, and provide real-time monitoring.

The proposed system's machine learning methods can significantly improve patient outcomes by ensuring that the medical oxygen supply is always of the required quality and quantity. The system also has the potential to reduce the workload of hospital staff members by automating the monitoring and management of the oxygen supply chain. However, it should be noted that the proposed system is not a replacement for human expertise and intervention. The system is designed to support hospital staff in managing the oxygen supply chain. However, human intervention and decision-making are still required to ensure medical oxygen's safe and effective use. In the next section, we discuss the limitations of the proposed system and areas for future research.

Discussion

In this study, we have presented the development of an intelligent system for managing medical oxygen consumption using oximetry and barometry in the hospitals of Mashhad University of Medical Sciences, utilizing machine learning methods. The system integrated various sensors and machine learning algorithms to enable real-time monitoring and control of the oxygen supply chain. The proposed system utilized multiple sensors to measure the purity and pressure of medical oxygen, and this data was collected and processed using machine learning algorithms. The method employed a decision tree model to classify the purity and pressure readings and identify deviations from the parameters. The system also used an artificial neural network model to predict future oxygen consumption levels, enabling proactive supply chain management. The results of testing the proposed system showed that it can effectively monitor and manage medical oxygen consumption with high accuracy and reliability. The machine learning algorithms used in the system have the potential to improve patient safety by identifying potential issues in the oxygen supply chain before they become critical. The proposed approach has several advantages over the traditional manual management of oxygen consumption, including reducing the workload of medical staff, improving the accuracy of data collection and analysis, and enabling proactive supply chain management. One of the limitations of the proposed system is its dependence on the availability of electricity and internet connectivity. In cases where these resources are not available or are unreliable, the system may not function properly. Another limitation is the cost associated with the installation and maintenance of the system, which may be a challenge for hospitals with limited budgets.

Conclusion

In conclusion, this study has presented an innovative and intelligent system that utilizes machine learning methods to enhance the management of medical oxygen consumption in hospitals significantly. The system can improve patient outcomes by ensuring the medical oxygen supply is always of the required quality and quantity. The proposed system consists of two main components: the hardware component and the software component. The hardware component includes the sensors used for data collection and an Arduino board for data processing. The software component consists of the machine learning algorithms used for data processing and managing the system. The proposed system was tested in several hospitals affiliated with Mashhad University of Medical Sciences, and the results showed that it can effectively monitor and manage medical oxygen consumption with high accuracy and reliability. The machine learning algorithms used in the system have the potential to improve patient safety by identifying potential issues in the oxygen supply chain before they become critical. Future work includes implementing the proposed system in other hospitals and evaluating its performance in different settings. Further research is needed to optimize the machine learning algorithms used in the design and to develop more advanced models for predicting oxygen consumption levels. Finally, the ethical considerations associated with developing and deploying intelligent systems in healthcare should be carefully considered, including privacy, data security, and patient autonomy.

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