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THE LATEST TECHNOLOGY IN EARLY DETECTION AND HANDLING OF FUNGUS IN HOSPITALS: A LITERATURE REVIEW

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ABSTRACT

Pathogenic fungi can cause serious infections in hospitals, especially in patients with weakened immune systems. Early detection and prompt management are crucial to reducing morbidity and mortality. The latest technology in fungal diagnosis and therapy holds great potential for improving clinical outcomes. This research is a literature review that examines various latest technologies used in the early detection and management of fungal infections in hospitals. Relevant articles from various medical and technology databases are selected and analysed to identify the latest trends in this field. The research findings indicate that various technologies, such as PCR-based detection, biosensor sensors, and advanced imaging technologies like MRI and CT scans, have demonstrated better capabilities in early fungal detection. Moreover, AI and machine learning-based approaches have shown great potential in optimising treatment and reducing diagnosis time. The latest technology in the detection and management of fungal infections in hospitals has shown significant progress. Further implementation of these technologies can accelerate diagnosis, improve treatment efficiency, and reduce the risk of complications. Further research is needed to evaluate the long-term effectiveness of this technology in clinical practice.

INTRODUCTION

Mould can pose a serious threat in hospital environments, especially to patients with weakened immune systems. Fungal infections can develop on damp walls or surfaces in healthcare facilities (Kanamori et al., 2015; Viegas et al., 2017), which can potentially lead to increased morbidity and mortality rates. Therefore, early detection and handling of mould are very important. Modern technology, such as humidity sensors, has been used to detect mould growth in real-time in hidden spaces, while UV-C light has been introduced for surface decontamination (Hosein et al., 2016; Savoury et al., 2012). Humidity sensors can monitor moisture on walls or areas prone to mould, allowing for earlier preventive measures. (Dou et al., 2019). UV-C light, which is effective in killing pathogens such as Candida albicans and Aspergillus niger, is also used to reduce fungal contamination on hospital surfaces. (Dashti et al., 2022; Santos & de Castro, 2021). Although this technology is promising, its long-term effectiveness in preventing fungal growth in various healthcare facilities is not yet fully understood, and the practical challenges in its implementation need to be further explored.

Although there is much evidence supporting the use of humidity and UV sensors, the long-term reliability of this technology has not been extensively studied, especially in detecting hidden moisture or in sensitive areas such as ICUs or operating rooms. (Lee & Jeong, 2020; Shabbir et al., 2023). Questions regarding the integration of this technology into hospital infection control systems and the costs of its implementation still need to be answered.

Further research is needed to evaluate the long-term effectiveness of this technology and identify practical challenges in its implementation. With the increasing prevalence of fungal infections in hospitals and concerns about microbial resistance, this research can provide new insights for the more efficient, safe, and sustainable management of fungal growth in healthcare facilities. (Dou et al., 2019).

This research will contribute to the development of more proactive and cost-effective infection prevention policies, which will ultimately improve the quality of patient care in hospitals.

RESEARCH METHODS

Design

This research uses a literature review design to evaluate the latest technologies in early detection and management of mould in hospitals. This method involves searching for and selecting articles through reputable international scientific databases, such as PubMed. The selection stage is carried out by filtering relevant articles based on quality and topic suitability using established inclusion and exclusion criteria. (Calley & Warris, 2017). Next, data from the selected articles is extracted and analysed to identify technological innovations used in the diagnosis and treatment of fungi, such as the use of PCR and biosensors for rapid detection. Somogyvari et al., 2012). The final results are then compiled into a report that summarises the main findings and provides recommendations for clinical practice and future research. Kozel & Wickes, 2014).

Search Metode

This research examines the literature on the latest technologies in early detection and management of fungi in hospitals, with a search period from 2014 to 2024. Literature is searched from online databases such as PubMed using several main search terms that cover various aspects. In the general technology category, terms such as mould detection technology and fungi detection in healthcare facilities are used. For specific technology categories, focus on technologies such as humidity sensors and the use of UV light with search terms like humidity sensor mould detection and UV disinfection mould hospital. In the context of healthcare, the search includes terms such as mould prevention healthcare facilities and hospital air quality monitoring old. In the advanced technology category, the search focuses on IoT-based technology with terms such as IoT moisture sensors and mold hospitals. In addition, aspects of technology effectiveness and implementation are also considered through terms such as cost-effectiveness mould detection technology hospital and technology implementation mould control hospital. All these terms were chosen to gather relevant literature on mould detection technology and its control in hospital environments.

Inclusion/Exclusion Criteria

The inclusion criteria in this study encompass all articles discussing the latest technologies in early detection and management of fungi in hospitals. The selected articles must be published in English between the years 2014 and 2024 to ensure that the research remains focused on modern technologies that are still in use or in the development stage. This aims to ensure that the technology discussed remains relevant and innovative while avoiding the use of outdated technology.

Exclusion Criteria. The following exclusion criteria are used: Articles published more than 10 years ago. With a shorter time frame, there will be a greater focus on the latest technology.

Study Selection

All database search results were exported to the Mendeley reference manager software, and duplicate search results were removed. Next, the selection process is carried out in two steps with the help of Excel. The first step is to select titles and abstracts from all articles that provide information about the latest technologies in early detection and handling of fungi in hospitals. Next, in the second step, reviewers screen the full text to determine its eligibility, and finally, the articles that meet the criteria are selected for further analysis.

Figure 1. PRISMA FLOW CHART

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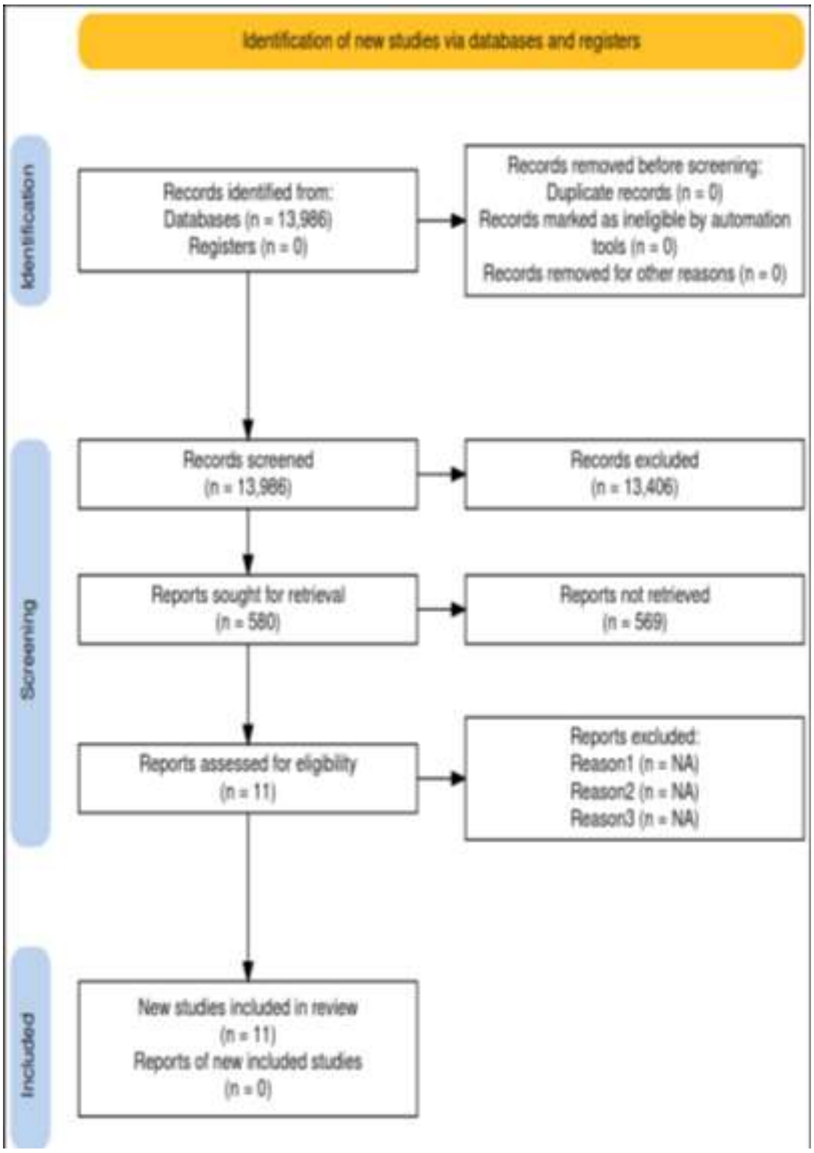

Extraction, Analysis, and Data Synthesis

The data was extracted using Excel. Initially, the articles were reread to gain a comprehensive understanding of their methodology and findings. Patterns in each article are identified. The authors grouped each relevant research response. Next, the authors noted the article authors, publication year, research objectives, research samples, research locations, research designs, and data analysis used.

Quality Assessment

Critical appraisal was conducted on 11 articles consisting of four types of studies: experimental, observational, cohort, and retrospective analytical study. The purpose of this assessment is to evaluate the quality of the methodology, the relevance of the variables, bias control, and the validity of the conclusions in each article. This evaluation ensures that only high-quality articles are used as the basis for further research.

In the experimental study category, five articles were assessed using the JBI checklist. All articles received the maximum score (15/15), indicating that this research excels in internal validity, sampling methods, experimental control, and the relevance of research findings. Articles in this category demonstrate very high methodological quality, making them the primary reference in this research.

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Next, four articles in the observational study category received an average score of 11/11. These articles excel in population selection, data collection methods, and the relevance of the measured variables. Nevertheless, controlling confounding factors remains a major challenge that, even when well managed, still requires attention in the interpretation of results.

In the cohort study, two analysed articles also received a perfect score (11/11). This article stands out in its research design that aligns with the objectives, controls for bias, and the relevance of the research findings. However, the sample sizes used in several cohort studies are relatively limited, so this needs to be considered when generalising the results.

For the retrospective analytical study, one article that was evaluated received a score of 14/15. This article demonstrates excellence in bias control, variable relevance, and the strength of conclusions supported by data. However, there is a slight deficiency in the reporting of specific data that could affect the overall context of the research.

The differences in characteristics between types of studies provide complementary strengths. Experimental studies have very good internal validity thanks to strict control methods. On the other hand, observational studies provide data that is more relevant to a broader population. Meanwhile, cohort studies and retrospective analytical studies offer a temporal dimension that helps provide insights into cause-and-effect relationships in specific contexts. The combination of these various types of studies provides a strong foundation to support further research.

The results of the critical appraisal show that all the articles analysed meet the established quality criteria. These articles are not only relevant to the research topic but also have a robust methodology and reliable conclusions. Experimental studies provide strong causal evidence, while observational, cohort, and retrospective analytical studies complement research with in-depth contextual and temporal data. Thus, the combination of these various types of studies significantly contributes to supporting the overall research objectives.

Table 1. THEMES IDENTIFIED FROM THE LITERATURE.

Theme and Subtheme	(Domínguez-Morueco et al., 2014)	(H. Wu et al., 2018)	(Hashimoto & Kawakami, 2018)	(Tršan et al., 2019)	(Afanou et al., 2019)	(La Milia et al., 2019)	(Park et al., 2019)	(Fan et al., 2021)	(Laurus chkat et al., 2021)	(Hemati et al., 2021)	(Fedor et al., 2022)
Air Monitoring/Screening			√	√	√	√	√	√		√	√
Mushroom Detection	√								√		
Environmental Monitoring											
Humidity Sensor	√	√				√					√
UV rays								√	√	√	
Potential Applications	√				√						
Implementation Challenges				√				√	√	√	√
Modern Technology	√	√	√			√	√	√	√	√	√
Conventional Methods					√						

RESULTS AND DISCUSSION

Study Characteristics

Article searches were conducted using the PUBMED database with main keywords such as mould detection technology, fungal contamination detection in hospitals, fungi detection in healthcare facilities, and environmental monitoring for mould control. Out of a total of 13,986 articles found, only 11 articles met the inclusion criteria after a strict selection based on the relevance of the research methods and publications in the last 10 years. The keyword "environmental monitoring for mould control" contributed the most to the final selection of articles.

These studies highlight various technologies and innovative approaches for early detection and handling of fungi in hospitals and laboratories. The main focus of the research includes the analysis of contaminated surfaces, air in clean rooms, and hospital environments such as haematology wards. Some studies use specific methods such as fungal colony counting (CFU), airborne particle measurement (APC), and galactomannan analysis from clinical patient fluids. Another study evaluated the impact of mouldy environments on at-risk groups, such as patients with haematological diseases and workers chronically exposed to mould.

The research designs applied vary, including laboratory experiments, cross-sectoral observations, and prospective cohorts. Laboratory experiments using microbiology-based bioassays, while field studies assess the efficiency of HEPA air purifiers in reducing mould concentrations. Observational research was conducted to monitor the hospital environment during renovations, with the collection of air and surface samples using modern techniques such as ATP bioluminescence and scanning electron microscopy.

Data analysis in this study uses statistical methods such as ANOVA, Poisson regression, and machine learning algorithms like random forest to classify immunological responses to fungal infections. Molecular identification through DNA sequencing supports the grouping of fungal species, while fungal growth prediction models provide simulations of contamination scenarios. The results of various studies show the importance of combining statistical, molecular, and predictive approaches to effectively understand and manage the risk of fungal contamination in hospitals.

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Table 2. SUMMARY OF THE ARTICLES.

NO	REFERENCES	RESEARCH PURPOSES	RESEARCH SAMPLE	RESEARCH LOCATION	RESEARCH DESIGN	DATA ANALYSIS USED
1	(Domínguez-Morueco et al., 2014)	Determining the sensitivity of lichen phycobionts (Asterochloris erici and Trebouxia sp. TR9) to pharmaceutical micropollutants, namely carbamazepine and diclofenac, as an initial step in developing a toxicity microbioassay.	Two strains of phycobionts, namely Asterochloris erici and Trebouxia sp. TR9, were tested with various concentrations of carbamazepine and diclofenac.	Departamento de Biología y Geología, ESCET, Universidad Rey Juan Carlos, Spain and Instituto Cavanilles de Biodiversidad y Biología Evolutiva, Universitat de Valencia, Spain.	Laboratory experiments using microbioassay-based bioassays with the main parameters being optical dispersion and chlorophyll autofluorescence.	Using ANOVA (Analysis of Variance) with the LSD (Least Significant Difference) test to determine significant differences between groups with a 95% confidence level ($p < 0.05$).
2	(H. Wu et al., 2018)	This study aims to highlight the importance of mold hygiene evaluation in building design and prior to environmental changes. In addition, this study also explores alternatives for sustainable mold control compared to 24-hour air conditioning.	The study identified eight areas contaminated with fungi in the laboratory, including a variety of surfaces (walls, tables, metal, and plastic), with seven species of fungi found.	The research was conducted in a laboratory at Hong Kong Baptist University, Kowloon Tong, Hong Kong, China.	This study used an observational experimental design with visual inspection, sampling from contaminated areas, and microbiological analysis to identify fungal species and environmental conditions.	Data were analyzed using molecular identification (DNA sequencing) to determine fungal species, measurement of environmental parameters (such as temperature and humidity), and the use of fungal growth prediction models to support contamination scenarios.
3	(Hashimoto & Kawakami, 2018)	This study aimed to evaluate the effectiveness of HEPA air-purifying fans in reducing indoor airborne mold concentrations, using direct measurements in six homes in Japan.	The research sample was six houses in Japan, each having a living room environment with wooden floors and a size of approximately 12 square meters.	The research location was six houses located in Tokyo, Kanagawa, and Chiba, Japan.	This study used a field experimental design by comparing the results of reducing airborne fungal concentrations using a HEPA air purifying fan under test conditions (fan on) and control conditions (fan off).	Data analysis involved calculating the clean air change rate in units per hour (h-1) and the ratio of indoor to outdoor mold concentrations (I/O ratio). The data was processed using a mass balance formula to determine the air cleaning efficiency.
4	(Tršan et al., 2019)	This study aimed to prepare a catalogue of cleanroom microbiota in four cleanrooms at the Pharmacy University Clinical Center Ljubljana (UKCL). This catalogue serves as a basis for assessing the suitability of rapid bioluminescence-based microbiological methods and comparing the results with classical microbiological methods.	The study involved 9,519 samples collected from four cleanrooms between 2011 and 2016. These samples included swabs from work surfaces, settle plates, and RODAC plates for active air analysis.	The study was conducted in four cleanroom Pharmacies at the University Clinical Center Ljubljana (UKCL), Slovenia.	This study used an observational design with routine collection of microbiological samples from air and surfaces, combined with classical microbiological testing and ATP bioluminescence methods to assess microbiological contamination.	Data analysis involved counting the number of colony forming units (CFU) per cubic meter (air) or per square centimeter (surface), and calculating the median number of colonies. Data were also used to evaluate changes in microbiota trends and the effectiveness of the ATP bioluminescence method.
5	(Afanou et al., 2019)	The purpose of this study was to characterize airborne fungal particles, including spores and fragments (submicron and large size), in a moldy basement and compare them with outdoor air. This study also explored differences in fungal particle composition by season (summer and autumn).	This study involved air samples from 7 moldy basements, 3 control basements, and 10 outdoor air locations. The total sample size was 20 locations.	The study locations were in Oslo, Norway, and one location in Østfold County, Norway, with a coastal climate environment.	This study used an observational experimental design with a stationary air particle sampling method in the basement and outdoor environment using scanning electron microscopy (FESEM) analysis to identify and quantify fungal particles.	Data were analyzed using non-parametric statistical methods (Kruskal-Wallis and Wilcoxon rank-sum tests) to compare groups, as well as mixed regression models with concentrated log ratio (clr) transformation to evaluate differences in fungal aerosol composition between locations and seasons.

6	(La Milia et al., 2019)	The aim of this study was to evaluate the impact of renovation activities on environmental contamination, specifically particles and fungal isolation, in a hospital hematology ward. This study also assessed the effectiveness of control measures, such as the use of HEPA filters and sanitation, to protect patients from the risk of invasive aspergillosis (IA) infection.	The study covered four construction areas involving a total of eight patient rooms in a hematology ward. Data collection included counting of airborne particles (APCs), fungal colonies (CFUs), and galactomannan samples from patient serum or bronchoalveolar fluid (BAL).	This study was conducted in the hematology ward of a large teaching hospital in Rome, Italy.	This study used an observational design with environmental sampling before, during, and after renovation. Renovation activities were carried out without stopping clinical activities, with strict environmental and clinical supervision.	Data analysis using particle concentration (APC) and fungal colony count (CFU) calculations, as well as galactomannan testing to detect aspergillosis infection. Statistical differences were tested using the chi-squared test or Fisher exact test using Stata IC 14 software.
7	(Park et al., 2019)	The aim of this study was to evaluate the association between airborne fungal spore contamination and the incidence of invasive aspergillosis (IA) in immunocompromised patients during the construction period in a tertiary hospital. This study also aimed to measure the levels of airborne fungal spores during various construction phases and assess their impact on the incidence of IA.	The sample included patients with hematological malignancies admitted to three hematology wards (2 adults, 1 pediatric) during the construction period. A total of 29 patients were diagnosed with IA based on EORTC/MSG criteria, as well as monthly collected air contamination data.	This study was conducted at Asan Medical Center, a tertiary hospital in Seoul, South Korea.	This study used a prospective cohort design involving air and patient surveillance during the construction period. The construction period was divided into two phases: heavy work (such as demolition and excavation) and light work (interior design, plumbing, and finishing).	Data were analyzed using Poisson regression to compare IA incidence rates between the two construction periods. Categorical variables were compared using the χ^2 or Fisher exact test, and continuous variables were analyzed using the Mann-Whitney U test. All analyses were performed using SPSS version 21.0.
8	(Fan et al., 2021)	This study aims to examine the distribution of cultivable fungi in the air in daily life scenarios in 12 major cities in China. The study also evaluates factors that influence the concentration of fungi in the air, such as environmental parameters, building characteristics, and family behavior.	The study involved a total of 642 households in 12 cities in China. Each household was sampled in the living room and bedroom during the summer and winter seasons in 2018.	The research locations covered 12 cities in China, including Harbin, Panjin, Shijiazhuang, Qingdao, Lanzhou, Luoyang, Xi'an, Wuxi, Ningbo, Mianyang, Shenzhen, and Nanning.	This study used a cross-sectional observational study design. Data collection was carried out by air sampling using a six-stage Anderson impactor, as well as a questionnaire survey to collect information related to building characteristics and family habits.	Data analysis was performed using a generalized linear model with a Poisson connection function to evaluate the relationship between RAF (Residential Airborne Fungi) and the influencing variables. Other statistical analyses included the Wilcoxon signed-rank test, Pearson correlation, and odds ratio (OR) calculation using R software version 3.6.3.
9	(Lauruschkat et al., 2021)	This study aims to evaluate the impact of chronic fungal exposure on the adaptive immune response, specifically the expansion of T-helper cells type 1 (Th1) and type 2 (Th2) reactive to Aspergillus antigens, and to analyze the possible use of these antigens in monitoring the bio-effects of fungal exposure in organic workers.	The study involved 10 organic farmers who were chronically exposed to fungi and 10 control individuals without professional fungal exposure.	The research was conducted in Germany, with subjects being organic farmers certified according to European Union standards.	The study used an experimental observational design with immunological analysis of T-helper cell responses using methods such as ELISPOT, flow cytometry, and blood-based cytokine release assays.	Data were analyzed using the Mann–Whitney U test for statistical significance, Spearman regression for correlation analysis, and machine learning algorithms (random forest) for classifying subjects based on their immunological responses. The software used included GraphPad Prism and R.
10	(Hemati et al., 2021)	This study aimed to simultaneously monitor the presence of SARS-CoV-2, bacteria, and fungi in the air in different rooms at Hajar Hospital, Shahrekord, Iran. This study also aimed to evaluate the relationship between the concentration of bacteria and fungi in the air and the presence of SARS-CoV-2, as well as assess the potential risk of nosocomial infections during the COVID-19 pandemic.	total of 107 air samples were taken, consisting of 45 samples for SARS-CoV-2 detection and 62 samples for monitoring airborne bacteria and fungi.	The study was conducted at Hajar Hospital, Shahrekord, Iran.	The study used an observational design with air sampling in various hospital rooms over a 10-day period. The monitored rooms included infectious disease rooms, ICU, radiology, and other areas related to COVID-19 patients.	Data were analyzed using descriptive statistics, one-way ANOVA to compare bacterial and fungal concentrations across chambers, and independent t-tests to correlate bacterial and fungal concentrations with the presence of SARS-CoV-2. The analysis was performed using IBM SPSS version 23 software.

11	(Fedor et al., 2022)	This study aims to verify the effectiveness of anti-epidemic measures in ensuring air quality in cleanrooms of tertiary hospitals through long-term monitoring of air quality in various cleanrooms.	The study involved 351 airborne particle samples and 256 microbiological samples taken from grade A cleanrooms over a 6-year period (2014-2019).	The research was conducted at University Hospital Olomouc, Czech Republic, which includes departments such as Pharmacy, Nuclear Medicine, and Assisted Reproduction.	The study used a retrospective analytical design with regular monitoring methods based on EN ISO 14644 standards and good pharmaceutical manufacturing practices (EU-GMP). The analysis was performed in a clean room in active and simulated operating modes.	Data were analyzed by calculating 95% confidence limits for particle air monitoring results using the particle counter's built-in software. Microbiological culture results were compared with contamination limits recommended by European standards.

Review Quality Assessment

The research results show that by using the JBI quality assessment tool, 11 studies have high methodological quality, as all articles received a "yes" rating for all relevant elements (Appendix B). No articles were excluded based on this data evaluation assessment system.

Latest Technologies in Early Detection and Management of Fungi in Hospitals

This study discusses various latest technologies in detecting and managing fungi in hospitals, with a focus on environmental monitoring and fungal growth control. Technologies such as microbioassays using moss algae to detect environmental pollutants (Domínguez-Morueco et al., 2014) and controlling humidity below 70% have proven effective in preventing mould growth. Wu et al., 2018). HEPA air purifiers and IoT-based humidity sensors have become key tools in mitigating mould contamination. (Hashimoto & Kawakami, 2018; La Milia et al., 2019). In addition, techniques such as ATP bioluminescence and galactomannan sensors can detect fungi more quickly and accurately compared to traditional methods (Lauruschkat et al., 2021; Tršan et al., 2019). UV-C technology and ventilation systems with HEPA filters have also proven effective in reducing mould spores, especially in high-humidity environments. (Fan et al., 2021).

However, the implementation of this technology in healthcare facilities faces challenges such as costs, the need for medical staff training, and integration with existing systems. Nevertheless, new technology offers faster and more proactive detection compared to conventional methods such as fungal culture. (Fedor et al., 2022).

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However, the implementation of this technology in healthcare facilities faces challenges such as costs, the need for medical staff training, and integration with existing systems. Nevertheless, new technology offers faster and more proactive detection compared to conventional methods such as fungal culture. (Fedor et al., 2022).

Comparison with conventional methods and modern methods such as galactomannan detection and environmental sensors is more efficient than traditional methods such as visual inspection and fungal culture. (La Milia et al., 2019). Real-time PCR techniques and bioaerosol air sampling systems enable faster and more specific detection compared to time-consuming culture-based methods. (Hemati et al., 2021). In addition, technologies such as immunogold-FESEM offer higher resolution for detecting fungi that are more difficult to identify. (Afanou et al., 2019).

Discussion

The results of this study make a significant contribution to filling the knowledge gap regarding the efficacy of the latest technologies in the early detection and management of fungi in hospitals. In previous literature, conventional methods such as humidity control and visual inspection were considered sufficient to prevent mould growth, but the results of this study show that modern technologies such as IoT-based humidity sensors and UV rays provide a spore reduction of up to 90%, far more effective than traditional methods. (Fan et al., 2021).

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Detection technologies such as real-time PCR and ATP-based bioluminescence have also proven to be faster and more accurate compared to manual microbial cultures, which are time-consuming and more prone to errors (Hemati et al., 2021; Tršan et al., 2019). This clarifies the need for modern solutions for bioaerosol management in hospital environments, especially in preventing nosocomial infections associated with fungal spores.

This research also fills a gap in understanding the management of fungal contamination during construction activities in hospitals. Previously, managing mould risk during construction often only involved general cleanliness procedures. However, this study shows the effectiveness of HEPA filters with positive pressure ventilation in significantly reducing the spread of Aspergillus spores. (Park et al., 2019).

In addition, innovative approaches such as cytokine-based immunoassays and ELISPOT expand the boundaries of early fungal detection capabilities in high-risk patients, which were previously difficult to achieve with standard serological methods or cultures. (Lauruschkat et al., 2021). The implication is an increased protection for the group of immunosuppressed patients, who are often exposed to the risk of invasive fungal infections during treatment.

However, this research also reveals challenges such as the high cost of installing modern technology and the need for additional training for medical personnel. Nevertheless, the long-term benefits of using this technology in reducing nosocomial infections can be considered worth the initial investment (Fan et al., 2021; Fedor et al., 2022).

By integrating this latest technology, this research not only fills the knowledge gap but also provides practical solutions to improve air quality and reduce the risk of mould in hospital environments.

Implications for Practice

The findings of this research have significant implications for managing fungal risks in hospitals. Technologies such as IoT-based humidity sensors and UV rays can be immediately implemented to monitor and control humidity in vulnerable areas, reducing mold growth by up to 90%. (Fan et al., 2021). Additionally, the use of HEPA filters in ventilation systems has proven effective in preventing the spread of Aspergillus spores during construction in healthcare facilities, making it highly relevant for implementation in hospitals with active renovation projects. (Park et al., 2019). For high-risk patients, the use of technology such as cytokine-based immunoassays can aid in the early detection of fungal infections, although it requires additional training for medical personnel. (Lauruschkat et al., 2021). With the adoption of this technology, healthcare institutions can enhance patient protection, reduce nosocomial infection rates, and create a safer working environment.

CONCLUSION

This research highlights the important role of modern technology in the early detection and management of fungi in hospitals. Technologies such as IoT-based humidity sensors, UV-C rays, and HEPA filters have proven effective in reducing the risk of fungal spore spread and improving air quality in healthcare facilities. These results show that technology-based approaches can significantly overcome the limitations of traditional methods, such as manual inspection and simple moisture control, which were previously the standard for managing mould risk. (Fan et al., 2021; Park et al., 2019).

These findings have significant implications for modern hospital management, especially in protecting high-risk patients such as those who are immunosuppressed. Proactive approaches such as cytokine-based immunotes provide solutions for early detection of nosocomial infection risks that were previously difficult to address with traditional methods. (Lauruschkat et al., 2021). Furthermore, the implementation of this modern technology offers the potential to reduce infection rates and enhance patient safety during activities such as hospital renovations, which typically increase the risk of mould spread in enclosed environments. (Park et al., 2019).

In the future, it is important to integrate this technology more widely in hospital management, considering challenges such as initial installation costs and medical staff training. Collaboration between policymakers, technology providers, and researchers will be key to ensuring that this

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innovation can be implemented effectively and sustainably. Thus, this research not only provides practical solutions but also lays the foundation for better strategies in preventing fungal infection risks in healthcare facilities.

CONFLICT OF INTEREST

The authors declare that there are no potential conflicts of interest related to the research, writing, and/or publication of this article.

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Appendix A. Literature searching strategies and results (November 2024).

Database	keyword	Search result
PubMed	mold detection technology	8,387
	fungal contamination detection in hospitals	2,931
	fungi detection in healthcare facilities	755
	“environmental monitoring for mold control”	1,007
	“humidity sensor mold detection”	16
	“moisture sensors hospital fungal control”	0
	“UV light mold treatment hospital”	71
	“UV disinfection mold hospital”	30
	“mold prevention healthcare facilities”	126
	“fungal contamination hospital environment”	4,303
	“hospital mold detection technology”	792
	“infection control mold hospital”	3,398
	“hospital air quality monitoring mold”	176
	“IoT moisture sensors mold hospital”	0
	“sensor technology mold hospital”	48
	“real-time monitoring mold healthcare”	18
	“smart sensors fungal detection hospital”	8
	“effectiveness of UV light mold removal hospital”	7
	“cost-effectiveness mold detection technology hospital”	6
	“technology implementation mold control hospital”	12
	“hospital mold detection strategies”	330
Total		**13986**
Final full text relevant to our review		**11**

APPENDIX B. JBI CRITICAL APPRAISAL CHECKLIST.

JBI Critical Appraisal Checklist for Experimental Studies

NO	ARTICLE	**PARAMETER**																
		Is the purpose of the research clearly explained? Just answer yes or no.	Is the sampling method explained and appropriate to the research objectives? Just answer yes or no.	Are the measured variables relevant to the research question?	Are there adequate controls in the experiment to minimize bias?	Are outcome measurements performed using validated tools or methods?	Are the populations or specimens used in the experiments well described?	Are the treatment and control groups described in detail?	Was the allocation of specimens to treatment groups random?	Is there any blinding applied (if relevant)?	Is the sample size sufficient to support the research findings?	Was the collected data analyzed using appropriate statistical methods?	Are the experimental results explained clearly and logically?	Does this study take into account relevant confounding factors?	Are the conclusions supported by the data and results obtained?	Can the research results be applied in a clinical or environmental context?	Are there any conflicts of interest or funding that could influence the results?	**Score out of**
1	-Morueco	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**15**
2	(H. Wu et al., 2018)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**15**
3	(Hashimoto & Kawakami, 2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	**15**
4	(Tršan et al., 2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	**15**
5	(Afanou et al., 2019)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**15**

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JBI Critical Appraisal Checklist for Observational Studies

NO		1. Are the research objectives clearly stated?	2. Is population selection well explained?	3. Are there controls for relevant confounding factors?	4. Are the data collection methods well described?	5. Are the measured variables relevant to the research question?	6. Is the research design appropriate to the research objectives?	7. Was the data analyzed using appropriate statistical methods?	8. Are bias and confounders well controlled?	9. Are the results explained clearly and logically?	10. Is the conclusion supported by the available data?	11. Can the research results be applied practically or clinically?	Is there a potential conflict of interest?	Score out of
1	(H. Wu et al., 2018)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	11
2	(La Milia et al., 2019)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	11
3	(Lauruschkat et al., 2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	11
4	(Hemati et al., 2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	11

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JBI Critical Appraisal Checklist for Cohort Studies

No		Are the research objectives clearly explained?	Is population selection well explained?	Are there controls for relevant confounding factors?	Are the data collection methods well described?	Are the measured variables relevant to the research question?	Is the research design appropriate to the research objectives?	Was the data analyzed using appropriate statistical methods?	Are biases and confounders well controlled?	Are the results explained clearly and logically?	Is the conclusion supported by the available data?	Can the research results be applied practically or clinically?	Is there a potential conflict of interest?	**Score out of**
1	(Park et al., 2019)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	11
2	(Fan et al., 2021)	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	11

JBI Critical Appraisal Checklist for Retrospective Analytical Studies

No		The purpose of the research is clearly explained.	The research design is in accordance with the research objectives.	Population selection is well described, including inclusion and exclusion criteria.	The groups compared are appropriate to the research objectives and relevant.	Relevant confounding factors are well controlled.	Data is collected using clear and valid methods.	The data collected is related to the research questions.	The variables measured are clear and relevant.	The statistical analysis used is appropriate to the type of data available.	The results were analyzed in a manner appropriate to the research design.	There are controls for bias (e.g., recall bias, selection bias).	The conclusion is supported by the existing results.	Conclusions can be applied practically or clinically.	There is a potential conflict of interest reported.	The information provided in the article is clear enough to understand the research methods and results.	**Score out of**
(Fedor et al., 2022)		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	14