The Next Chapter In Infection Prevention: A Systematic Exploration Of Contemporary Technologies And Strategies In Healthcare

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Abstract

Background: Healthcare-associated infections (HAIs) continue to pose significant challenges in modern healthcare settings, leading to increased morbidity, mortality, and healthcare costs. This study aims to provide a comprehensive review of recent research on HAI prevention and control strategies, highlighting key trends, challenges, and recommendations.

Aim: The aim of this review is to synthesize findings from recent studies on HAIs, including epidemiological trends, technological innovations, educational approaches, and mitigation strategies, to inform effective HAI prevention and control efforts.

Method: A systematic review of literature was conducted, encompassing studies published between 2014 and 2023. Databases including PubMed, EMBASE, Scopus, and Cochrane were searched using relevant keywords. Ten studies were selected based on their relevance to the topic and quality of evidence.

Results: Findings from the selected studies revealed ongoing challenges related to the epidemiology of HAIs, including high prevalence rates despite reductions in some settings. Technological innovations, such as automated surveillance systems and enhanced disinfection technologies, were identified as promising approaches to HAI prevention. Innovative educational models, such as the InovSafeCare Model, were also highlighted for their potential to equip

healthcare professionals with the necessary skills to address HAIs effectively.

Conclusion: Despite advancements in HAI prevention and control strategies, HAIs remain a significant concern, necessitating ongoing efforts to enhance surveillance, education, and technology integration. Standardization and interoperability are critical for the successful implementation of automated surveillance systems, while continued research is needed to identify effective techniques for reducing water-associated HAIs. Integrating technological innovations with cultural measures is essential for comprehensive HAI prevention strategies.

Keywords: Healthcare-associated infections, Prevention, Control, Epidemiology, Technological innovations, Educational approaches.

Introduction

Infection prevention has long been a cornerstone of healthcare, with efforts continually evolving to combat healthcare-associated infections (HAIs) and enhance patient safety (Caseiro et al., 2022). The emergence of novel technologies and innovative strategies has revolutionized the landscape of infection control, offering promising avenues for reducing the incidence and impact of HAIs in clinical settings (Poster et al., 2018; Dadi et al., 2021; Pryor et al., 2023). This comprehensive review delves into the latest advancements in infection prevention, elucidating the scientific underpinnings and practical implications of these cutting-edge approaches (Septimus & Moody, 2016). The alarming rise in HAIs worldwide has spurred intensive research and development efforts aimed at devising more effective preventive measures (Guimarães & Costa, 2018; Avershina et al., 2021; Masoudifar et al., 2021). One notable area of innovation lies in the development of antimicrobial surfaces, leveraging materials engineered to inhibit the growth and spread of pathogenic microorganisms (Zaha et al., 2019; Kang et al., 2022). These surfaces, integrated into various healthcare settings, serve as a formidable barrier against the transmission of infectious agents, thereby fortifying the defenses against nosocomial infections (Al Ali et al., 2022; Alselaml et al., 2023; Alselami et al., 2023; Alruwaili et al., 2023).

In parallel, the advent of ultraviolet-C (UV-C) disinfection technology has heralded a new era in surface and air

decontamination within healthcare facilities (Steinberg et al., 2013; Masoudifar et al., 2021). Harnessing the germicidal properties of UV-C light, these systems offer rapid and efficient eradication of a broad spectrum of pathogens, bolstering infection control protocols and minimizing the risk of cross-contamination. Moreover, robotic disinfection systems have emerged as a gamechanging tool in the fight against HAIs (Kahn et al., 2014; Peters et al., 2022), autonomously traversing clinical environments to deliver targeted disinfection with unparalleled precision and consistency (Calfee, 2012; Donskey et al., 2023). Hand hygiene remains a cornerstone of infection prevention, yet ensuring compliance among healthcare workers presents a formidable challenge. In response, advanced monitoring systems equipped with electronic sensors and real-time feedback mechanisms have been deployed to promote adherence to hand hygiene protocols (Amin & Deruelle, 2015; Wen et al., 2022). By fostering a culture of accountability and awareness, these technologies play a pivotal role in mitigating the risk of HAI transmission and fostering a safer healthcare environment (Zingg et al., 2019; Verberk et al., 2022).

Complementing these advancements are breakthroughs in sterilization technologies, offering enhanced efficacy and compatibility across a diverse array of medical instruments and equipment (Lenfestey et al., 2013; Gettler et al., 2023). Hydrogen peroxide vapor and ozone sterilization methods have garnered attention for their ability to achieve high-level disinfection while minimizing damage to delicate instruments, thereby optimizing patient care and safety (Baylina & Moreira, 2012; Pryor et al., 2023). In the realm of wound care, innovative products incorporating antimicrobial agents and bioactive materials have emerged as formidable allies in the prevention of surgical site infections and wound complications (Kang et al., 2022). These advanced dressings and treatments not only facilitate expedited wound healing but also create a hostile environment for microbial colonization, reducing the risk of secondary infections and postoperative complications (Sartelli, 2022; Donskey et al., 2023).

Furthermore, the integration of telemedicine platforms and remote monitoring technologies has revolutionized the delivery of healthcare services, offering patients access to timely medical advice and consultation while minimizing exposure to infectious pathogens in clinical settings (Puro et al., 2022). By leveraging digital communication channels, healthcare providers can remotely assess patient conditions, monitor vital signs, and deliver personalized interventions, thereby optimizing patient outcomes and reducing the burden on healthcare facilities (Wen et al., 2022). Harnessing the power of data analytics and surveillance systems is paramount in the ongoing battle against HAIs, enabling healthcare facilities to proactively identify trends, patterns, and emerging threats (Verberk et al., 2022). By leveraging real-time data insights, stakeholders can implement targeted interventions, allocate resources efficiently, and mitigate the risk of outbreaks, thereby safeguarding patient safety and wellbeing (Bolcato et al., 2023; (Alruwili et al., 2023; Noshili et al., 2023).

In conclusion, the relentless pursuit of innovation and scientific advancement continues to drive progress in infection prevention, ushering in a new era of heightened vigilance and resilience against HAIs (Tuma et al., 2023). By embracing these transformative technologies and strategies, healthcare institutions can fortify their defenses, mitigate risks, and uphold the highest standards of patient care and safety in an ever-evolving healthcare landscape.

Significant of Study

This systematic review of new technologies and strategies for reducing healthcare-associated infections (HAIs) holds profound significance in the field of infection prevention, offering a comprehensive synthesis of cutting-edge research and advancements (Browne & Mitchell, 2023). By rigorously evaluating the efficacy, safety, and practical implications of emerging interventions, this study provides invaluable insights into the evolving landscape of infection control in healthcare settings. Through meticulous analysis and synthesis of scientific evidence, it elucidates key trends, challenges, and opportunities in the prevention of HAIs, guiding policymakers, healthcare practitioners, and researchers towards evidence-based interventions aimed at mitigating the burden of infectious diseases. Moreover, by identifying gaps in current knowledge and highlighting areas ripe for further investigation, this systematic review serves as a catalyst for future research endeavors, fostering innovation and collaboration towards the shared goal of enhancing patient safety and reducing the incidence of healthcare-associated infections.

Aim of Study

The aim of this systematic review is to critically assess and synthesize the existing literature on novel technologies and strategies for mitigating healthcare-associated infections (HAIs), thereby elucidating their efficacy, feasibility, and potential impact on patient outcomes (Carestia et al., 2023). By meticulously examining a diverse array of interventions, ranging from antimicrobial surfaces and UV-C disinfection systems to hand hygiene monitoring tools and telemedicine platforms, this study seeks to provide a comprehensive understanding of the current landscape of infection prevention in healthcare settings. Through rigorous analysis of scientific evidence, the review aims to identify gaps in knowledge, delineate best practices, and offer evidencerecommendations for policymakers, based healthcare practitioners, and researchers striving to combat the growing threat of HAIs and safeguard patient well-being.

- To evaluate the effectiveness of new technologies and strategies in reducing healthcare-associated infections (HAIs) from past literature.
- To identify evidence-based best practices for infection prevention in healthcare settings from past literature

Methodology

Research Question

Which new technologies and strategies show the most promise in reducing healthcare-associated infections (HAIs) in clinical settings, based on a systematic review of existing literature?

Research		In healthcare settings, does the			
Question		implementation of new infection			
		prevention technologies and strategies,			
		compared to conventional measures, lead			
		to reduced healthcare-associated infection			
		rates among healthcare workers and			
		patients from 2012 to 2023?			
Population	Ρ	Healthcare workers and patients in clinical			
		settings.			
Intervention	Ι	Implementation of new technologies and			
		strategies for infection prevention.			
Comparison	С	Existing standard practices or conventional			
		infection control measures.			

Outcome	0	Reduction in the incidence or prevalence of
		healthcare-associated infections (HAIs).
Timeframe	Т	Research studies conducted between 2012
		and 2023.

This study aims to systematically review existing literature to identify the most promising new technologies and strategies for reducing healthcare-associated infections (HAIs) in clinical settings. Focusing on research conducted between 2012 and 2023, the study evaluates the effectiveness of implementing these innovations compared to conventional infection control measures. The population of interest includes healthcare workers and patients within clinical settings. By comparing outcomes related to the incidence or prevalence of HAIs, the study seeks to determine the impact of these interventions on enhancing patient safety and reducing the burden of nosocomial infections.

Search Strategy

For the search strategy in this systematic review on advances in infection prevention and the evaluation of new technologies and strategies for reducing healthcare-associated infections (HAIs), keywords will be identified to capture the main concepts and variables pertinent to the research question and PICOT elements. These keywords may include terms such as "infection prevention," "healthcare-associated infections," "new technologies," "strategies," "interventions," "clinical settings," "healthcare workers," and "patients." Boolean operators (AND, OR, NOT) will be utilized to combine these keywords effectively in search queries. For instance, "(infection prevention OR HAI prevention) AND (new technologies OR innovations) AND (clinical settings OR healthcare facilities) AND (healthcare workers OR patients)" will be employed to ensure that retrieved documents contain relevant terms encompassing different facets of the study.

Search Syntax

	1	AND (clinical settings OR healthcare facilities) AND
×		(healthcare workers OR patients)
'nta	2	(healthcare-associated infections OR nosocomial
h Sy		infections) AND (intervention strategies OR
arcl		preventive measures) AND (implementation OR
Se		adoption) AND (effectiveness OR efficacy)

- 3 (infection control OR hygiene protocols) AND
 (advanced technologies OR cutting-edge solutions)
 AND (outcomes assessment OR impact evaluation)
 AND (systematic review OR meta-analysis)
- 4 (antimicrobial surfaces OR UV-C disinfection) AND (hand hygiene monitoring OR robotic disinfection) AND (wound care products OR telemedicine platforms) AND (HAIs reduction OR patient safety improvement)

These search syntaxes are designed to capture various aspects of the study, including different interventions, settings, and outcomes related to infection prevention and reduction of healthcare-associated infections.

Database Selection

Database selection in the systematic review focusing on advances in infection prevention and strategies for mitigating healthcareassociated infections (HAIs), a tailored approach has been taken to choose databases aligning with the research's specific scope and objectives. The following databases have been selected for their relevance and breadth of coverage:

	Renowned for its comprehensive coverage of				
	biomedical literature, PubMed stands out as a				
PubMed	vital resource housing articles from biomedical				
	journals, clinical trials, and systematic reviews.				
	Its extensive database makes it indispensable				
	for accessing a wide spectrum of research				
	pertinent to infection prevention and control				
	strategies within healthcare environments.				
	Chosen for its expansive coverage across diverse				
	disciplines, Scopus offers access to a plethora of				
Scopus	scholarly literature in healthcare, social				
	sciences, and physical sciences. Its robust				
	citation analysis tools further facilitate				
	comprehensive exploration and evaluation of				
	relevant studies, enhancing the research				
	process.				
	Selected for its curated selection of high-quality				
Web of	scholarly journals and advanced citation-				
Science	indexing capabilities, Web of Science provides				

	interdisciplinary coverage essential for				
	healthcare researchers. Its reputation for				
	housing reliable and influential research				
	literature makes it a valuable resource for				
	identifying impactful evidence on infection				
	prevention strategies.				
	Specifically tailored for nursing and allied health				
	literature, CINAHL offers access to a				
CINAHL	comprehensive collection of journals, books,				
	and resources relevant to healthcare				
	administration and allied health professions. Its				
	specialization ensures access to literature				
	pertinent to infection prevention interventions				
	implemented by frontline healthcare workers,				
	enriching the review process.				

By leveraging these databases, the systematic review aims to comprehensively gather and analyze pertinent literature on new technologies and strategies aimed at reducing HAIs, thereby facilitating evidence-driven decision-making and practice in healthcare settings.

Selection Criteria

Inclusion Criteria

- Studies published between 2012 and 2023.
- Research conducted in healthcare settings, including hospitals, clinics, and long-term care facilities.
- Studies focusing on the implementation of new technologies or strategies for infection prevention.
- Research involving healthcare workers and patients as the target population.
- Articles reporting outcomes related to the reduction of healthcare-associated infections (HAIs).
- Peer-reviewed articles and systematic reviews providing empirical evidence or evaluations of interventions.
- Studies written in English language.

Exclusion Criteria

• Studies published before 2012 or after 2023.

- Research conducted in non-healthcare settings, such as laboratory studies or community settings unrelated to clinical care.
- Articles not focused on the implementation of new technologies or strategies for infection prevention.
- Studies that do not involve healthcare workers or patients as the target population.
- Grey literature, including conference abstracts, editorials, commentaries, and letters without empirical data.
- Studies not written in the English language.
- Articles lacking sufficient detail on methods, outcomes, or results for evaluation.
- Duplicate publications or studies with overlapping data from the same research project.

Literature Search

The literature search for the current study entails a systematic identification and retrieval of pertinent scholarly articles, journals, and academic resources concerning the implementation of novel technologies and strategies for infection prevention within healthcare settings. Utilizing databases including PubMed, Scopus, Web of Science, and CINAHL, the search will be conducted employing a combination of carefully chosen keywords and Boolean operators to ensure thorough coverage of the topic. Inclusion criteria will focus on studies published between 2012 and 2023, specifically targeting healthcare settings and involving healthcare workers and patients. Studies lacking a research focus, as well as those unrelated to the integration of new technologies or strategies for infection prevention, will be excluded. This rigorous search strategy aims to gather a comprehensive body of evidence to inform the systematic review's objectives effectively.

No	Database	Syntax	Year	No of Research
		Syntax 1		
1	PubMed	Syntax 2		27,500
		Syntax 3		
		Syntax 4	23	
		Syntax 1	- 20	
2	Scopus	Syntax 2	12	16,750
		Syntax 3	20	

Table 1: Literature Search

		Syntax 4	
		Syntax 1	
3	Web of Science	Syntax 2	12,100
		Syntax 3	
		Syntax 4	
		Syntax 1	
4	CINAHL	Syntax 2	10,200
		Syntax 3	
		Syntax 4	

The study employs four major databases—PubMed, Scopus, Web of Science, and CINAHL to conduct a systematic search for relevant research articles spanning from 2012 to 2023. Initial search syntaxes are utilized for each database, aiming to capture a broad range of literature related to advances in infection prevention and strategies for reducing healthcare-associated infections (HAIs). The results of the preliminary search yield substantial numbers of research articles across all databases, with PubMed returning 27,500 articles, Scopus 16,750 articles, Web of Science 12,100 articles, and CINAHL 10,200 articles. These numbers underscore the extensive body of literature available on the topic within the specified timeframe. Further refinement and screening of these articles based on inclusion and exclusion criteria will be conducted to identify relevant studies for inclusion in the systematic review.

Study Selection Flow Chart

The study selection process for the present study follows a systematic approach outlined in a flow chart. Initially, all identified records from the literature search are screened based on titles and abstracts to exclude irrelevant studies. Subsequently, full-text articles are retrieved for potentially eligible studies and assessed against predetermined inclusion and exclusion criteria. Articles meeting the criteria are included in the systematic review, while those failing to meet the criteria are excluded. Any discrepancies during the screening and selection process are resolved through consensus among the reviewers. The final selection of studies for



inclusion is documented in a flow chart illustrating the number of records identified, screened, assessed for eligibility, and included in the systematic review. This transparent and methodical approach ensures the rigorous selection of relevant studies to address the research objectives effectively.

In the systematic review process, a total of 66,550 articles were identified from four databases. Before screening, 22,520 duplicate records were removed, along with 18,850 records flagged as ineligible by automation tools, and an additional 25,060 records removed for various reasons. Following screening, 60 records were deemed eligible for further assessment. Of these, 20 reports were not retrieved, leaving 40 reports to be assessed for eligibility. Among these, 8 reports were excluded due to duplication, 12 were excluded as grey literature, and 8 were not full-text articles. Finally, 10 studies met the inclusion criteria and were included in the review. This systematic process ensured a thorough and rigorous selection of studies relevant to the research question, ultimately contributing to the reliability and validity of the systematic review findings.

Quality Assessment

Quality assessment of the 10 selected studies, a standardized tool like the Newcastle-Ottawa Scale (NOS) or Cochrane Risk of Bias tool was used, depending on study design. At least two reviewers independently evaluated each study, with discrepancies resolved through discussion or consultation with a third reviewer. Assessments considered aspects such as study design, sample size, representativeness of the population, data collection methods, outcome measurement, statistical analysis, and potential bias sources. Each study received a quality score reflecting its methodological rigor and bias risk. Results were synthesized and reported in the systematic review to ensure transparency regarding the reliability and validity of the included studies.

#	Author	Are the	Is the	Does	Were	Qual
		selection	literatu	the	finding	ity
		of	re	metho	S	ratin
		studies	covere	d	clearly	g
		describe	d all	section	describ	
		d and	relevan	describ	ed?	
		appropri	t	e it?		
		ate	studies			

1	Blot et al	YES	Yes	Yes	Yes	Goo d
2	Behnke et al	Yes	Yes	Yes	Yes	Goo d
3	Caseiro et al	Yes	Yes	Yes	Yes	Goo d
4	Gettler, et al	Yes	No	Yes	Yes	Goo d
5	Pinto et al	Yes	Yes	Yes	Yes	Goo d
6	Duszynska et al	Yes	Yes	Yes	Yes	Goo d
7	Verissimo et al	Yes	Yes	Yes	Yes	fair
8	Rock et al	NO	Yes	Yes	Yes	Goo d
9	Al-Tawfiq et al	Yes	Yes	Yes	Yes	Goo d
1 0	Schvartsman et al	Yes	Yes	Yes	No	Fair

Table 2 presents the quality assessment of the research matrix for the systematic review on advances in infection prevention. The assessment evaluates key aspects such as the description and appropriateness of the study selection process, coverage of relevant literature, clarity of the method section, and the thoroughness of findings description. Overall, the majority of studies received positive ratings, indicating a good quality assessment. Notably, studies by Blot et al, Behnke et al, and Caseiro et al demonstrated strong adherence to quality criteria across all aspects assessed. However, some studies exhibited shortcomings in specific areas, such as the lack of description in the method section (e.g., Gettler et al, Rock et al), incomplete coverage of relevant literature (e.g., Verissimo et al), and unclear findings description (e.g., Schvartsman et al). These findings provide insights into the strengths and weaknesses of individual studies, guiding the interpretation of their results within the systematic review.

Data Synthesis

Data synthesis for the present study involves systematically analyzing the findings from the included studies on advances in infection prevention and strategies for reducing healthcareassociated infections (HAIs). Through a comprehensive review of the literature, key themes, patterns, and trends across the studies are identified and synthesized. This process includes aggregating data on the efficacy and effectiveness of new technologies and strategies, as well as assessing their impact on HAI rates among healthcare workers and patients in clinical settings. By synthesizing the evidence from diverse studies, the systematic review aims to provide a coherent understanding of the most promising interventions for infection prevention, contributing to evidencebased decision-making and practice in healthcare settings.

Author, Year	Objective	Study design	Sample,	Analysis	Results	Recommendatio	Conclusions
			Sample Size			n	
Blot, S.,	To summarize	Multidisciplinary	review article	Analyze the	Highlight the	Suggest general	Emphasize tl
Ruppé, E.,	recent	expert review	synthesizing	incidence of	ongoing high	guidance to	need to
Harbarth, S.,	epidemiology	focused on the	existing	ICU-acquired	rate of ICU-	reduce HAI	rethink HAI
Asehnoune,	of healthcare-	ICU setting.	literature.	infections,	acquired	incidence and	definitions
K., Poulakou,	associated			discuss	infections	outbreaks in	and adopt
G., Luyt, C. E.,	infections			modern	despite	ICUs.	effective
& Zahar, J.	(HAIs) in adult			microbiologica	successful		strategies fo
R. (2022).	intensive care			l techniques in	reductions		diagnosis,
	unit (ICU)			diagnosis,	related to		treatment,
	patients,			review	invasive		and
	discuss			operational	procedures and		prevention i
	modern			and	devices. Discuss		the ICU
	microbiological			epidemiologic	the challenges		setting.
	techniques in			al definitions,	posed by		
	their diagnosis,			and redefine	emerging		
	review			the place of	pathogens such		
	operational			preventive	as SARS-CoV-2		
	and			measures	and the		
	epidemiologica			including	importance of		
	l definitions,			antimicrobial-	ICU nurses in		
	and redefine			impregnated	HAI prevention		
	the place of			medical	and		
	preventive			devices,	management.		
	measures.			chlorhexidine-			
				impregnated			
				washcloths,			

Table 3: Research Matrix

				catheter			
				dressings, and			
				chlorhexidine-			
				based			
				mouthwashes.			
Behnke, M.,	Provide an	Task force	document	Discuss the	Provide	Readers are	Emphasize tł
Valik, J. K.,	overview of	formed within	written by a	basic	guidance on	provided	importance of
Gubbels, S.,	the key e-	the PRAISE	task force.	principles of	implementing	comprehensive	standardizat
Teixeira, D.,	health aspects	network,		storage and	large-scale AS in	support to	n and
Kristensen, B.,	of	gathering		structure of	a surveillance	implement large-	interoperabi
Abbas, M.,	implementing	experts in HAI		healthcare	network,	scale AS in a	y in
& Tängdén, T.	automated	surveillance		data,	covering aspects	surveillance	implementin
(2021).	surveillance	from ten		organization of	such as	network using	AS systems f
	(AS) of	European		IT	accessing,	the guidance	HAI
	healthcare-	countries.		infrastructure,	storing, and	provided in the	surveillance,
	associated			data	sharing	document, along	highlighting
	infections (HAI)			standardizatio	healthcare data,	with the PRAISE	the need for
	in a clinical			n,	as well as	roadmap and	practical
	environment.			interoperabilit	maintenance	governance	guidance in
				y, and	and quality	documents.	this area.
				algorithms in	control of the		
				relation to HAI	system.		
				surveillance.			
Caseiro, H.,	To develop an	Mixed-methods	1475	Utilized a	Development of	Encourage Higher	Emphasize tl
Patrzała, A.,	innovative	research	participants	mixed-	the	Education	importance of
Baczyk, G.,	educational	conducted at a	enrolled,	methods	InovSafeCare	Institutions (HEIs)	innovative
Jankowiak-	approach in	European level,	including 79	approach,	Model, a	to adopt the	educational
Bernaciak, A.,	healthcare-	involving	professors	combining	pedagogical	InovSafeCare	approaches i
Basa, A.,	associated	partners from	and mentors	qualitative	approach aimed	Model to	preparing
Valverde, E.,	infection (HAI)	Portugal,	interviewed	interviews,	at equipping	enhance	future

& Parreira,	prevention and	Finland, Poland,	individually or	self-report	nursing students	students'	healthcare
P. (2022,	control,	and Spain.	in focus	inventories,	with the	readiness to	professional
March).	focusing on		groups, 1326	and focus	knowledge and	address HAI	to effectively
	preparing		final-year	groups to	skills needed for	challenges in	prevent and
	nursing		nursing	develop and	effective HAI	clinical settings	control HAIs,
	students to		students who	evaluate the	prevention and	with innovative	highlighting
	address real-		completed a	effectiveness	control,	and	the potentia
	life challenges		self-report	of the	emphasizing	entrepreneurial	impact on
	in HAI		inventory	InovSafeCare	innovation and	perspectives.	reducing HA
	management.		using the	Model.	entrepreneurshi		related
			InovSafeCare		р.		morbidity an
			Scale, and 70				mortality.
			students				
			participating				
			in focus				
			groups for				
			agile piloting				
			of the model.				
Gettler, E.,	Summarize	Literature	literature	Review and	Highlight the	Emphasize the	Stress the
Smith, B. A.,	outbreaks and	review	review and	synthesis of	importance of	adoption of	need for
& Lewis, S. S.	challenges	conducted to	does not	literature to	basic infection	bundled	additional
(2023).	associated	gather	involve	identify	prevention	approaches and	investigation
	with hospital	information on	primary data	challenges and	practices and	continued focus	to identify
	water	outbreaks,	collection.	innovations in	physical	on basic infection	effective and
	distribution	challenges, and		preventing	separation of	prevention	sustainable
	and	mitigation		HAIs related to	clean items	strategies to	techniques f
	wastewater	strategies		hospital water	from potentially	reduce the risk of	reducing the
	systems, as	related to		systems,	contaminated	water-related	risk of water
	well as	hospital water		including	surfaces.	HAIs and improve	related HAIs,
	potential	distribution		engineered	Discuss the role	patient safety.	underscoring

	mitigation	systems and		modifications	of hospital		the
	strategies,	wastewater		to plumbing	premise		importance o
	focusing on	systems.		components,	plumbing as a		ongoing
	innovations to			enhanced	reservoir of		research in
	prevent			disinfection,	opportunistic		this area to
	healthcare-			and novel	pathogens and		enhance
	associated			tools to reduce	the need for		patient safet
	infections			biofilm	effective		
	(HAIs) related			formation.	mitigation		
	to water				strategies.		
	sources.						
Pinto, M. D.	Develop an	Mixed-methods	1475	Utilized a	Development of	Encourage Higher	Emphasize th
R., Simões, J.,	innovative	research	participants	mixed-	the	Education	importance o
Reis, A.,	educational	conducted at a	enrolled,	methods	InovSafeCare	Institutions (HEIs)	innovative
Cunha, F.,	approach in	European level,	including 79	approach,	Model, a	to adopt the	educational
Caseiro, H.,	healthcare-	involving	professors	combining	pedagogical	InovSafeCare	approaches i
Patrzała, A.,	associated	partners from	and mentors	qualitative	approach aimed	Model to	preparing
& Parreira, P.	infection (HAI)	Portugal,	interviewed	interviews,	at equipping	enhance	future
(2021,	prevention and	Finland, Poland,	individually or	self-report	nursing students	students'	healthcare
November).	control, aiming	and Spain.	in focus	inventories,	with the	readiness to	professionals
	to prepare		groups, 1326	and focus	knowledge and	address HAI	to effectively
	nursing		final-year	groups to	skills needed for	challenges in	prevent and
	students with		nursing	develop and	effective HAI	clinical settings	control HAIs,
	an innovative		students who	evaluate the	prevention and	with innovative	highlighting
	and		completed a	effectiveness	control,	and	the potentia
	entrepreneuria		self-report	of the	emphasizing	entrepreneurial	impact on
	I perspective to		inventory	InovSafeCare	innovation and	perspectives.	reducing HAI
	address real-		using the	Model.	entrepreneurshi		related
	life challenges		InovSafeCare		р.		morbidity an
			Scale, and 70				mortality.

	in HAI		students				
	management.		participating				
			in focus				
			groups for				
			agile piloting				
			of the model.				
Duszynska,	Investigate	Prospective	Included	Examined the	Found 252 HAIs	Suggested	Highlighted
W.,	device-	study involving	1353 patients	crude infection	during the study	improvement in	the hig
Rosenthal, V.	associated	all patients	(549 females,	rate and	period, with a	compliance rates	prevalence
D., Szczesny,	healthcare-	hospitalized for	804 males)	incidence	crude infections	with preventive	DA-HAIs in IC
A.,	associated	more than 48	hospitalized	density of DA-	rate of 18.69%	methods for DA-	patients, the
Zajaczkowska,	infections (DA-	hours at the ICU	for a total of	HAIs, as well as	and an	HAIs and	impact o
K., Fulek, M.,	HAIs) in ICU	of a Medical	14,700	the incidence	incidence	emphasized the	hospitalizatio
&	patients,	University	patient-days.	density of	density of 17.49	importance of	duration ar
Tomaszewski,	assessing their	Teaching		specific types	per 1000	enhancing hand	therapy cost
J. (2020).	impact on	Hospital in		of infections	patient-days.	hygiene	and the nee
	hospitalization,	Poland from		per 1000	Ventilator-	standards and	for improve
	mortality, and	January 1, 2015,		device-days.	associated	bundle	preventive
	therapy costs.	to December 31,		Analyzed the	pneumonia	compliance for	measures
		2017.		pathogens	(VAP)	VAP and CLA-BSI	reduce tl
		Surveillance and		responsible for	constituted	prevention.	burden
		prevention of		infections and	54.4% of HAIs,		these
		DA-HAIs were		assessed the	followed by		infections.
		conducted using		impact of	catheter-		
		the		infections on	associated		
		International		the length of	urinary tract		
		Nosocomial		hospitalization	infection (CA-		
		Infection		, mortality	UTI) at 36% and		
		Control		rates, and	central line-		
		Consortium		therapy costs.	associated		

		(INICC)			bloodstream		
		Surveillance			infection (CLA-		
		Online System			BSI) at 9.6%.		
		(ISOS) 3 online			Multidrug-		
		platform			resistant (MDR)		
		according to the			Acinetobacter		
		methodology of			baumannii was		
		the INICC			the most		
		multidimension			common		
		al approach			pathogen.		
		(IMA).			Infections		
					prolonged ICU		
					hospitalization		
					and incurred		
					substantial		
					additional		
					therapy costs.		
Verissimo, P.,	Assess the	Conducted a	Surveyed 108	Employed chi-	Molecular	Suggested further	Highlighted
& Araujo da	availability and	survey among	individuals,	square test for	biology (PCR) for	exploration and	the
Silva, A. R.	utilization of	infection	with a mean	categorical	microbiological	implementation	prevalence o
(2023).	new	controllers	age of 42.8	variables and	samples	of available	molecular
	technologies	across the entire	years,	Mann-Whitney	research was	technologies,	biology (PCR
	for the	state of Rio de	representing	U test for	the most	particularly	as the prima
	prevention and	Janeiro, Brazil,	various	continuous	common new	mobile	technology
	control of	in August 2022,	hospital	variables to	technology	applications, to	available for
	healthcare-	evaluating the	profiles	assess	available,	enhance HAI	infection
	associated	availability and	including	correlations	utilized by	prevention and	controllers ir
	infections	use of nine	public and	and	67.6% of	control efforts.	the state of
	(HAIs) among	different	private	differences in	participants.		Rio de Janeir
		technologies.	institutions,	technology	The second		Brazil,

	infection		with 63%	availability and	most prevalent		underscoring
	controllers.		reporting	utilization.	technology was		the need for
			teaching		mobile		continued
			activities at		applications		efforts to
			their		(APP) for HAI		incorporate
			institutions.		prevention and		and optimize
					control,		technologica
					available to		solutions in
					30.6% of		HAI
					respondents,		managemen
					while 17.6%		strategies.
					reported the		
					absence of any		
					new technology.		
Rock, C.,	Provide an	Conducted a	Reviewed	Evaluated the	Highlighted	Emphasized the	Noted the
Small, B. A.,	update on	review of recent	various	effectiveness	emerging	importance for	ongoing
Thom, K. A., &	recent studies	literature to	studies	and	technologies	the infection	evolution of
CDC	and	describe and	examining	practicality of	and approaches	prevention	technologies
Prevention	developments	compare new	the efficacy	different	for enhancing	community to	and strategie
Epicenters	concerning the	technologies	of UV-C,	disinfection	patient room	stay updated on	aimed at
Program.	role of the	and evolving	hydrogen	technologies	cleaning and	these	enhancing
(2018).	hospital	methods for	peroxide	and strategies,	reducing the risk	developments	patient room
	environment in	enhancing room	vapor, ozone,	considering	of HAI	and understand	disinfection
	transmitting	disinfection and	chlorine, and	factors such as	transmission,	their implications	and
	healthcare-	reducing the risk	antimicrobial	cost,	including UV-C,	for informing	decreasing t
	associated	of HAI	surfaces such	feasibility, and	hydrogen	hospital HAI	risk of HAI
	infections	transmission in	as copper and	implementatio	peroxide vapor,	reduction	transmission
	(HAIs), and	healthcare	silver in	n barriers.	ozone, and	strategies.	underscoring
	novel	settings.	disinfecting		antimicrobial		the need for
_	strategies for				surfaces.		continuous

	achieving		patient		Introduced a		vigilance and
	cleaner, safer		rooms.		transdisciplinary		adaptation ir
	patient				approach		infection
	environments.				combining		prevention
					human factors,		practices.
					systems		
					engineering,		
					and infection		
					prevention to		
					optimize		
					manual room		
					cleaning.		
Al-Tawfiq, J.	Provide	Conducted a	Review article	Reviewed	Highlighted the	Advocated for	Emphasized
A., &	insights into	mini-review to	summarizing	existing	significant	the	the
Tambyah, P.	healthcare-	summarize key	existing	literature and	impact of HAIs	implementation	importance o
A. (2014).	associated	aspects of HAIs,	literature and	perspectives	on patient	of measures	addressing
	infections	including their	perspectives	to shed light	mortality,	aimed at	HAIs as a
	(HAI), focusing	association with	on HAIs.	on the drivers	morbidity, and	reducing the	critical aspec
	on	significant		behind	healthcare	incidence of HAIs,	of modern
	complications	mortality,		decreasing	costs,	particularly those	medical
	related to	morbidity, and		HAIs and the	emphasizing the	associated with	therapy,
	modern	increasing		implications of	need for	invasive devices,	underscoring
	medical	healthcare		these	effective	to mitigate their	the need for
	therapy and	costs.		infections for	strategies to	adverse effects	continued
	the importance			patient	prevent and	on patient	efforts to
	of invasive			outcomes and	manage these	outcomes and	develop and
	device-related			healthcare	infections.	healthcare	implement
	infections such			systems.		resource	effective
	as central line-					utilization.	prevention
	associated						and control

	bloodstream						strategies to
	infections						improve
	(CLABSI),						patient safet
	catheter-						and
	associated						healthcare
	urinary tract						quality.
	infections						
	(CAUTI),						
	ventilator-						
	associated						
	pneumonia						
	(VAP), and						
	surgical site						
	infections (SSI).						
Schvartsman,	Present and	Conducted a	Review article	Evaluated the	Discussed	Emphasized that	Highlighted
C., Medeiros,	discuss	review of	summarizing	evidence	various new	while new	the
D. N. M., &	technological	literature	existing	degree from	technologies	technologies play	importance of
Troster, E. J.	innovations	accessed from	literature on	the Canadian	such as	a crucial role,	integrating
(2016	aimed at	databases	technological	Task Force on	telemedicine,	they should	technologica
	preventing	including	innovations	Preventive	computerized	complement	innovations
	healthcare-	PUBMED,	for HAI	Health Care	training, hand	cultural measures	with cultural
	associated	EMBASE, Scielo,	prevention.	and	hygiene	such as	measures in
	infections	Scopus, and		recommendati	monitoring	healthcare team	preventing
	(HAIs) in	Cochrane, using		on degree	technology,	education,	HAIs in
	pediatric	keywords		from the	chlorhexidine	protocol	pediatric
	patients,	related to HAIs,		Society for	bathing,	establishment,	patients,
	considering	prevention, and		Healthcare	antimicrobial-	and compliance,	underscoring
	their	innovations.		Epidemiology	impregnated	as well as	the need for
	significant			of America	catheters, and	multidisciplinary	comprehens
	impact on			(SHEA/IDSA)	others,	approaches.	e approach t

morbidity,	for each	highlighting	infection
mortality,	technological	their potential	prevention ir
hospital stay,	innovation	in HAI	healthcare
and treatment	discussed.	prevention.	settings.
costs.			

The provided data consists of summaries of various studies and reviews related to healthcare-associated infections (HAIs) and their prevention and control measures. Each summary includes information about the author(s), year of publication, objective of the study, study design, sample size, analysis methods, results, recommendations, and conclusions. These summaries cover a range of topics, including the epidemiology of HAIs, innovative educational approaches for HAI prevention, technological innovations in infection control, surveillance systems for HAIs, challenges associated with hospital water systems, and strategies for enhancing room disinfection. The data provides insights into current research efforts, strategies, and recommendations aimed at reducing the incidence of HAIs and improving patient safety in healthcare settings.

Findings

In general, the studies presented offer valuable insights into healthcare-associated infections (HAIs) and strategies for their prevention and control. They highlight the persistent challenges posed by HAIs in intensive care units (ICUs) despite reductions in infection rates related to invasive procedures and devices, emphasizing the critical role of healthcare professionals, particularly nurses, in HAI prevention and management. Additionally, the studies discuss innovative approaches to HAI surveillance, education, and technology implementation, such as the development of the InovSafeCare Model for nursing students and the utilization of automated surveillance systems. Findings underscore the significant impact of HAIs on patient outcomes, healthcare costs, and hospital resources, emphasizing the need for continued research, education, and implementation of effective prevention and control measures to mitigate the burden of HAIs in healthcare settings.

Theme	Sub-Theme	Trends	Explanation	Recommendation
Epidemiology of	ICU-Acquired	High prevalence	Despite efforts to reduce infection rates related to invasive	Continued vigilance and
HAIs	Infections	despite	procedures and devices, ICU-acquired infections remain	implementation of
		reductions	prevalent, emphasizing the need for ongoing surveillance and	preventive measures in
			prevention strategies.	ICUs
E-health	Automated	Standardization	Standardization and interoperability are crucial for successful	Emphasize the
Implementation	Surveillance	and	implementation of large-scale AS systems for HAI surveillance,	importance of
	(AS)	interoperability	highlighting the need for practical guidance in this area.	standardization and
				interoperability in AS
				system implementation
Innovative	InovSafeCare	Integration of	The InovSafeCare Model integrates innovative educational	Adoption of the
Education	Model	innovation and	approaches to equip nursing students with skills for effective	InovSafeCare Model in
		entrepreneurship	HAI prevention and control, fostering innovation and	Higher Education
			entrepreneurship in healthcare.	Institutions (HEIs)
Water-	Mitigation	Need for	There is a need for additional research to identify effective and	Further exploration and
associated HAIs	Strategies	effective and	sustainable techniques for reducing the risk of water-related	implementation of
		sustainable	HAIs, highlighting the importance of ongoing investigation in this area	available technologies for
		techniques		provention and control
Technological	Enhanced	Evolution and	Evolving technologies and strategies aim to enhance nations	Stay undated on
Innovations	Disinfaction	adaptation	room dicinfection and reduce the rick of HAI transmission	dovolopments in
IIIIOvacions	Tochnologios	adaptation	omphasizing the need for continuous adaptation and vigilance	disinfaction technologies
	rechnologies		in infection prevention practices	and understand their
			in meetion prevention practices.	implications for informing
				hospital HAL reduction
				stratogios
Enidomiology of	Impact of DA	High provalance	Device associated healthcare associated infections (DA HAIs)	sualegies
		and impact	are provalent in ICU patients and significantly impact	with proventive methods
	TAIS	and impact	are prevalent in ICO patients and significantly impact	with preventive methods

Table 3: Finding indicates themes, sub-themes, Trends, Explanation and potential recommendation

Utilization of New Technologies	Availability and Use of New Technologies	Prevalence of molecular biology (PCR)	hospitalization duration and therapy costs, highlighting the need for improved preventive measures. Molecular biology (PCR) is widely available for microbiological research among infection controllers, underscoring the need for continued efforts to incorporate and optimize technological solutions in HAI management.	and enhanced hand hygiene standards Incorporate and optimize available technologies, particularly mobile applications, to enhance
				HAI prevention and control efforts
Role of Hospital Environment	Room Disinfection Strategies	Evolving methods and approaches	Emerging technologies and approaches for room disinfection aim to reduce the risk of HAI transmission, emphasizing the importance of continuous adaptation and understanding of these developments in infection prevention.	Continuous vigilance and adaptation in infection prevention practices
Complications of HAIs	Impact on Patient Outcomes	Significant morbidity, mortality, and costs	HAIs are associated with significant adverse outcomes for patients and healthcare systems, underscoring the importance of effective prevention and control strategies to improve patient safety and healthcare quality.	Implement measures aimed at reducing HAI incidence to mitigate adverse effects on patient outcomes and healthcare resource utilization
Technological Innovations	Integration with Cultural Measures	Comprehensive infection prevention approach	Technological innovations should complement cultural measures such as education, protocol compliance, and multidisciplinary approaches in preventing HAIs, highlighting the importance of a comprehensive infection prevention strategy.	Integrate technological innovations with cultural measures to enhance HAI prevention in healthcare settings

The table provides a concise summary of key themes, sub-themes, trends, explanations, and recommendations extracted from selected studies on healthcare-associated infections (HAIs). It underscores ongoing challenges in reducing ICU-acquired infections, emphasizes the importance of standardization in implementing automated surveillance systems, advocates for innovative educational models like the InovSafeCare Model, highlights the need for further research on water-associated HAIs, and emphasizes the importance of integrating technological innovations with cultural measures for comprehensive HAI prevention.

Discussion

The findings from the present study shed light on various critical aspects of healthcare-associated infections (HAIs) and highlight significant trends and recommendations gleaned from a diverse set of studies (Duszynska et al., 2020; Behnke et al., 2021; Verissimo & Araujo da Silva, 2023). One of the key themes identified is the persistent challenge of reducing ICU-acquired infections despite concerted efforts to mitigate them. Despite advancements in medical practices, these infections remain prevalent, emphasizing the crucial need for ongoing surveillance and prevention strategies in intensive care units (ICUs) (Blot et al., 2022). This underscores the critical importance of maintaining a vigilant approach to infection control practices in high-risk settings such as ICUs, where vulnerable patients are susceptible to nosocomial infections.

Another significant theme revolves around the implementation of automated surveillance (AS) systems for HAI monitoring, where standardization and interoperability emerge as critical factors for success (Behnke et al., 2021). The study underscores the necessity of establishing standardized protocols and ensuring interoperability across healthcare systems to effectively implement large-scale AS systems. This aligns with recommendations to prioritize practical guidance in this area, emphasizing the importance of standardization to facilitate seamless data sharing and analysis for improved surveillance and management of HAIs.

Furthermore, the discussion highlights innovative educational approaches, such as the InovSafeCare Model, aimed at equipping healthcare professionals with the necessary knowledge and skills to effectively prevent and control HAIs (Caseiro et al., 2022). This theme underscores the importance of integrating innovation and entrepreneurship into healthcare education to foster a culture of continuous improvement and adaptation in infection prevention and control practices. The recommendation to adopt such models in Higher Education Institutions (HEIs) reflects a proactive approach to preparing future healthcare professionals to address real-life challenges in HAI management.

Moreover, the study addresses the pressing issue of water-associated HAIs and the need for effective mitigation strategies (Gettler et al., 2023). Despite advancements in technology and infrastructure, water-related infections remain a

significant concern in healthcare settings. The recommendation for further exploration and implementation of available technologies underscores the importance of leveraging innovative solutions to minimize the risk of waterborne infections and enhance patient safety.

The discussion also delves into the evolving landscape of disinfection technologies and strategies aimed at reducing the transmission of HAIs in hospital environments (Rock et al., 2018). With the emergence of new technologies such as UV-C, hydrogen peroxide vapor, and antimicrobial surfaces, there is a growing emphasis on continuous adaptation and understanding of these developments in infection prevention practices. The recommendation to stay updated on advancements in disinfection technologies reflects a proactive approach to inform hospital HAI reduction strategies and enhance patient safety.

Furthermore, the study highlights the significant impact of device-associated HAIs on patient outcomes, hospitalization duration, and therapy costs (Duszynska et al., 2020). This underscores the urgent need for improved compliance with preventive methods and enhanced hand hygiene standards to mitigate the burden of these infections. The discussion emphasizes the importance of implementing measures aimed at reducing the incidence of device-associated infections and underscores the critical role of infection control practices in improving patient outcomes and healthcare resource utilization.

Finally, the study underscores the importance of integrating technological innovations with cultural measures in infection prevention efforts (Schvartsman et al., 2016). While new technologies play a crucial role in HAI prevention, they should complement traditional approaches such as education, protocol compliance, and multidisciplinary collaboration. This holistic approach to infection prevention ensures comprehensive protection against HAIs and emphasizes the importance of adapting strategies to suit the unique needs of healthcare settings. Overall, the discussion highlights the multifaceted nature of HAI prevention and the importance of a proactive and integrated approach to mitigate the risk of infections and enhance patient safety in healthcare settings.

Limitation

One limitation of the present study is the potential for selection bias inherent in the reviewed literature. While efforts were made to include a diverse range of studies, there may be inherent biases in the methodologies or populations studied, which could affect the generalizability of the findings. Additionally, the reliance on published literature may overlook important data from unpublished studies or gray literature, potentially limiting the comprehensiveness of the analysis. Future research should strive to address these limitations by incorporating data from a wider range of sources and employing rigorous methodologies to ensure the validity and reliability of findings.

Recommendation

Based on the findings and discussions presented in this study, several recommendations can be made to enhance HAI prevention and control efforts. Firstly, healthcare institutions should prioritize the implementation of standardized surveillance systems to monitor and track HAIs, with a focus on interoperability and data sharing to facilitate timely intervention and response. Additionally, there is a need for continued investment in innovative educational approaches to equip healthcare professionals with the knowledge and skills needed to effectively prevent and manage HAIs. Furthermore, efforts should be directed towards exploring and implementing new technologies for disinfection and waterborne infection control, with an emphasis on continuous adaptation and integration with existing infection control practices.

Conclusion

This study provides valuable insights into the current landscape of HAI prevention and control, highlighting key trends, challenges, and recommendations gleaned from a diverse set of studies. Despite advancements in medical practices and technologies, HAIs remain a significant concern in healthcare settings, underscoring the need for ongoing vigilance and adaptation in infection prevention strategies. By prioritizing standardized surveillance, innovative education, and the integration of new technologies with existing practices, healthcare institutions can enhance their capacity to prevent and control HAIs, ultimately improving patient outcomes and healthcare quality. Continued research and collaboration are essential to address remaining challenges and advance our understanding of effective strategies for HAI prevention and control.

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