

Prevalence of Nosocomial Infections and Prevention and Control Strategies in Iranian Hospitals: A Mixed-Methods Study

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Abstract

Background: Hospital-acquired infections (HAIs) remain a major threat to patient safety and healthcare efficiency in Iran, contributing to increased morbidity, mortality, and healthcare costs.

Aim: This study aimed to estimate the overall prevalence of HAIs in Iranian hospitals and identify the most effective strategies for their prevention and control.

Method: A sequential explanatory mixed-methods design was employed. In Phase One, a systematic review and meta-analysis were conducted [on studies] published up to May 20, 2024, following Gough's nine-step framework, PRISMA 2020, and the PIO framework. In Phase Two, a two-round Delphi technique was used to develop and prioritize evidence-based strategies for reducing HAIs, informed by the findings of Phase One.

Results: A total of 22 studies conducted between 1999 and 2020 reported hospital-acquired infection (HAI) prevalence ranging from 0.046% to 26.5%. In the second phase, the Delphi process initially identified 82 potential strategies, which were refined through expert consensus (agreement >70%) during a face-to-face meeting. Ultimately, 56 context-specific strategies were finalized, with an emphasis on feasibility within Iranian clinical settings. These strategies focused on improving hand hygiene compliance, appropriate ventilation in high-risk units, strengthening infection control training, proper reprocessing of linens and medical equipment, establishment of infection prevention and control (IPC) committees, implementation of locally adapted evidence-based IPC guidelines informed by national surveillance and hospital data, timely and safe patient discharge, and effective hospital accreditation programs.

Implications for Practice: Although published studies suggest a low prevalence of HAIs in Iranian hospitals, effective prevention and control remain essential. Prioritizing locally adapted infection prevention guidelines, staff training, hand hygiene, appropriate ventilation, and safe discharge practices can address key challenges in Iranian clinical settings.

Keywords: Iran, Meta-Analysis, Nosocomial Infections, Prevalence, Systematic Review

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Introduction

Hospitals are among the most complex social and organizational systems, delivering diagnostic, therapeutic, and rehabilitative services through the coordinated use of human resources, technology, and infrastructure. Ensuring safe and high-quality care is a fundamental expectation of patients and a core objective of healthcare systems. However, rapid technological advancements, the increasing use of invasive diagnostic and therapeutic procedures, prolonged survival of immunocompromised patients, and extensive antibiotic utilization have collectively contributed to the persistent and growing burden of hospital-acquired infections (HAIs) worldwide (1-3).

Hospital-acquired infections are defined as infections that occur at least 48 hours after hospital admission or within 72 hours following discharge, provided that the infection was neither present nor incubating at the time of admission (4, 5). Despite advances in infection prevention and control, HAIs remain one of the most challenging global public health problems. It is estimated that approximately 7 out of every 100 hospitalized patients in developed countries and nearly 10 out of every 100 patients in developing countries acquire at least one HAI during their hospital stay (6).

Multiple patient-related and healthcare-related factors increase the risk of HAIs, including extremes of age, malnutrition, prolonged hospitalization, admission to intensive care units, and the use of invasive devices such as urinary and vascular catheters, mechanical ventilation, and surgical drains (7, 8). Surgical interventions, prior operative history, immunosuppressive therapy, and impaired consciousness further elevate this risk. Among HAIs, urinary tract infections, respiratory tract infections, bloodstream infections, and surgical site infections are the most frequently reported (9).

Globally, surveillance data indicate substantial variation in the prevalence and incidence of HAIs. For example, the European Centre for Disease Prevention and Control reported a prevalence of approximately 5.7% across 30 European countries in 2012 (10). In contrast, a systematic review has shown that the pooled prevalence of HAIs in developing countries is considerably higher, estimated at around 15.5% (11). In Iran, available studies report highly heterogeneous prevalence estimates ranging from 0.32% to 9.1% (12). This wide variability reflects differences in study design, hospital settings, surveillance systems, diagnostic criteria, and reporting quality, highlighting the absence of a comprehensive and reliable national estimate of HAIs in the country.

Beyond their clinical consequences, HAIs impose a substantial economic burden on healthcare systems. They are associated with prolonged hospital stays, delayed recovery, increased disability, reduced quality of life, and higher morbidity and mortality (13-15). In Europe, HAIs are estimated to cause approximately 16 million additional hospital days annually, leading to 37,000 direct deaths and contributing to an additional 110,000 deaths, with direct costs of about €7 billion (16). Country-level analyses have demonstrated that excess length of stay due to HAIs ranges from 4 to 14 days, resulting in millions of euros in additional healthcare expenditures (17). In Iran, recent evidence from 2023 indicates that the median additional cost attributable to surgical site infections per patient exceeds 33 million Rials (approximately 997 USD), underscoring the growing economic impact of HAIs within the national healthcare system (18).

Despite the high burden and clinical importance of hospital-acquired infections in Iran, the available evidence remains fragmented and heterogeneous, often limited to specific types of infections, restricted time periods, or particular hospital settings. Consequently, a comprehensive and up-to-date national estimate based on a systematic synthesis of all available data is still lacking. Moreover, there is no structured consensus on effective and context-specific strategies for the prevention and control of HAIs within the Iranian healthcare system.

To address these gaps, a meta-analysis is methodologically justified to aggregate and synthesize existing Iranian studies, reduce random error, explain heterogeneity, and provide a more precise and reliable estimate of the burden of HAIs at the national level. Furthermore, given the complexity of HAIs and the multifactorial nature of their prevention, the Delphi technique is an appropriate complementary approach to systematically capture expert consensus and prioritize feasible, context-sensitive strategies for reducing HAIs in Iran.

Therefore, the present study aims to (1) estimate the pooled prevalence of hospital-acquired infections in Iran through a systematic review and meta-analysis, and (2) develop and prioritize evidence-based strategies for HAI prevention and control using a Delphi approach. By integrating quantitative synthesis with expert consensus, this study seeks to fill a critical knowledge gap and provide actionable guidance for improving patient safety and healthcare quality in Iranian hospitals.

Methods

This sequential explanatory mixed-methods study was conducted in two integrated phases. In the first phase, a systematic review and evidence synthesis were performed following Gough's nine-step protocol to estimate the prevalence of nosocomial infections in Iranian hospitals. This included defining the research question, setting inclusion criteria, identifying search strategies, screening and selecting studies, extracting and synthesizing data, and evaluating study quality (19). The PRISMA 2020 flow diagram was used to visualize the study selection process (20), and the PIO framework—Population (patients), Intervention (clinical services), and Outcomes (nosocomial infections)—guided the design and analysis. The primary research question in this phase was: “What is the rate of hospital-acquired infections in Iranian hospitals based on available studies?”

Table 1: The search strategy and number of studies obtained from databases and search engines

Databases	Search Strategy	Initial Search
Pub Med	((("nosocomial infection"[All Fields] OR "hospital infection"[All Fields] OR "healthcare-associated infection"[All Fields]) AND "hospital-acquired infection"[All Fields] AND ("epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "prevalence"[All Fields] OR "prevalence"[MeSH Terms] OR "prevalance"[All Fields] OR "prevalences"[All Fields] OR "prevalence s"[All Fields] OR "prevalent"[All Fields] OR "prevalently"[All Fields] OR "prevalents"[All Fields] OR ("epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "incidence"[All Fields] OR "incidence"[MeSH Terms] OR "incidences"[All Fields] OR "incident"[All Fields] OR "incidents"[All Fields]) OR ("epidemiologies"[All Fields] OR "epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "epidemiology"[MeSH Terms] OR "epidemiology s"[All Fields]) OR ("epidemiology"[MeSH Subheading] OR "epidemiology"[All Fields] OR "frequency"[All Fields] OR "epidemiology"[MeSH Terms] OR "frequence"[All Fields] OR "frequences"[All Fields] OR "frequencies"[All Fields])) AND ("hospital s"[All Fields] OR "hospitalisation"[All Fields] OR "hospitalization"[MeSH Terms] OR "hospitalization"[All Fields] OR "hospitalised"[All Fields] OR "hospitalising"[All Fields] OR "hospitality"[All Fields] OR "hospitalisations"[All Fields] OR "hospitalizations"[All Fields] OR "hospitalize"[All Fields] OR "hospitalized"[All Fields] OR "hospitalizing"[All Fields] OR "hospitals"[MeSH Terms] OR "hospitals"[All Fields] OR "hospital"[All Fields]) AND ("iran"[MeSH Terms] OR "iran"[All Fields])) AND ((frrft[Filter]) AND (english[Filter] OR persian[Filter]))	3
Scopus	ALL ("nosocomial infection" OR "hospital infection" OR "healthcare-associated infection" AND "hospital-acquired infection") AND ALL (hospital) AND ALL (prevalence OR incidence OR epidemiology OR frequency) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Persian")) AND (LIMIT-TO (EXACTKEYWORD , "Article")) AND (LIMIT-TO (AFFILCOUNTRY , "Iran")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (OA , "all"))	152
Web of Science	((ALL=("nosocomial infection" OR "hospital infection" OR "healthcare-associated infection" AND "hospital-acquired infection")) AND ALL=(prevalence OR incidence OR epidemiology OR frequency)) AND ALL=(hospital))Refined By:Open Access. Document Types: Article. Languages: English. Countries/Regions: IRAN. Open Access: All Open Access	79
Magiran	"nosocomial infection"	450
SID	"nosocomial infection"	260
Google Scholar	("nosocomial infection" OR "hospital infection" OR "healthcare-associated infection" AND "hospital-acquired infection") AND (prevalence OR incidence OR epidemiology OR frequency) AND hospital AND Iran	2110
Final		3054

The second phase employed the Delphi technique to develop and prioritize context-specific strategies for reducing nosocomial infections. Importantly, the findings from the first phase directly informed the second phase by identifying the most prevalent infections and high-risk areas, ensuring that the strategies generated were evidence-based and targeted. By combining quantitative synthesis with structured expert consensus, this mixed-methods design allowed for a comprehensive understanding of both the burden of nosocomial infections and feasible interventions tailored to the Iranian

healthcare context. The literature search was conducted across multiple databases, including PubMed, Web of Science, Scopus, the Scientific Information Database (SID), Magiran, and Google Scholar, to ensure comprehensive coverage of relevant studies. The search strategy was refined through an iterative process starting with a preliminary search. This involved analyzing keywords and index terms from the initial retrieved articles. The search string was initially developed in MEDLINE with the assistance of an experienced medical librarian. The keywords were then translated into other databases using the Systematic Review Accelerator Polyglot search tool (21), and manually reviewed and adjusted as necessary. Key terms included nosocomial infection, hospital infection, healthcare-associated infection, hospital-acquired infection, prevalence, incidence, epidemiology, frequency, hospital, and Iran (Table 1). The search was run on 20 May 2024.

The selection of studies was carried out in three phases. Initially, a preliminary assessment was made by reviewing the titles and abstracts of identified publications to gauge their potential relevance. This was followed by a comprehensive evaluation of the full texts of selected publications against all specified inclusion and exclusion criteria. Finally, a manual search was conducted through the reference lists of included publications. Both reviewers refined the criteria. Each phase was independently conducted by three reviewers. Any disagreements were resolved through discussion or, if necessary, with the input of a fourth reviewer.

The initial search yielded 3054 studies. After removing duplicates and articles without full text, 2184 articles remained. The research team reviewed the titles and abstracts, eliminating 2154 unrelated articles. The full text of 30 remaining articles was assessed, and 8 were excluded due to low quality. Ultimately, 22 articles were selected for final analysis (Figure 1).

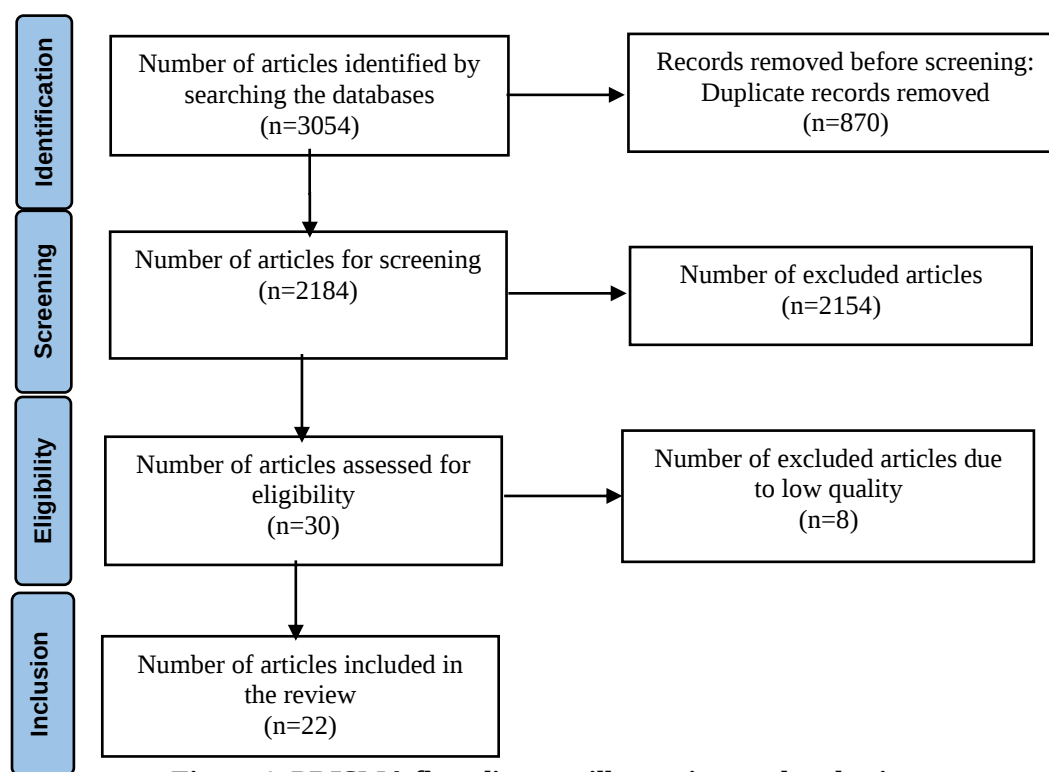


Figure 1. PRISMA flow diagram illustrating study selection process

The criteria for selecting studies in this systematic review were designed to include original quantitative research articles published in Persian or English that reported the prevalence of nosocomial infections in Iranian hospitals. Eligible studies focused on all hospital patients and all types of nosocomial infections, without restriction to specific wards or infection types, ensuring comprehensive national coverage. Studies were excluded if they were published in languages other than Persian or English, published after May 20, 2024, review articles, books, or qualitative studies, lacked data on the prevalence of nosocomial infections, focused on a specific type of infection, addressed infections in a single hospital ward, or were not available in full text. Accordingly, this review included only original quantitative studies providing comprehensive prevalence data across all

patients and hospital settings in Iran, allowing for a reliable synthesis that reflects the overall burden of nosocomial infections nationwide. The quality of all the identified articles was evaluated by two of the authors using Newcastle-Ottawa scale (22). This adapted scale comprises three main categories: Selection, Comparability, and Outcome, with a total possible score of 12, which surpasses the original maximum score of 10. Studies scoring 10 or more are generally considered to have a good quality, while those scoring below this threshold may be viewed as having potential biases or limitations in their design and execution. The data extraction form included the first author's name, year, study location, study population, sample size, data collection tools, mean patient age, patient hospital stay duration, hospital infection rate, quality score, and the most common microorganism (Table 2).

Table 2. Characteristics of the identified articles

Author/ (reference)	Year	Province	Hospital number	Sample size	Patients with hospital- acquired infections	Prevalence	The most common type of infection	Common microorganism	Average age of patients	Quality score
Shojaei (66)	2012	Qom	1	12668	97	0.76	Surgery site	Pseudomonas	42	11
Rahmanian (67)	2016	Fars	2	55295	177	0.32	Urinary tract	Escherichia coli	44.5	12
Ghorbani (68)	2010	Zanjan	1	34814	206	0.59	Respiratory system	Pseudomonas	37	10
Pezeshki (69)	2007	Iran	95	1879356	10557	0.57	Urinary tract	-	43.6	11
Askarian (70)	2006	Fars	1	4013	166	4.14	Urinary tract	-	42.6	12
Sohrabi (71)	2005	Semnan	1	23816	98	0.41	Urinary tract	Escherichia coli	55.7	11
Farzianpour (72)	2012	Qazvin	3	25628	242	0.94	Urinary tract	-	55.8	11
Larypoor (73)	2007	Qom	1	21054	105	0.35	Urinary tract	Escherichia coli	64.1	11
Kazemian (74)	2014	Ardebil	5	62601	2163	3.5	Urinary tract	Escherichia coli	-	11
Ghanbari (75)	2013	Esfahan	1	5500	300	5.4	Urinary tract	Escherichia coli	57	11
Rahimi-Bashar (76)	2016	Hamedan	1	10332	266	2.6	Respiratory system	Escherichia coli	58.1	12
Rahbar (77)	1999	West Azerbaijan	1	6492	593	9.1	Blood flow	-	-	12
Saeidimehr (78)	2013	Khuzestan	1	16936	174	2.03	Urinary tract	Escherichia coli	51.7	11
Bijari (79)	2012	South Khorasan	3	39777	358	0.9	Respiratory system	Klebsiella	37.6	11
Nasiri (80)	2017	Tehran	1	11164	369	3.3	Blood flow	Acinetobacter	-	10
Yaghubi (81)	2013	Gilan	1	738	42	5.7	Urinary tract	Acinetobacter	--	10
Sepandi (82)	2017	Tehran	1	14517	250	1.7	Urinary tract	Klebsiella	-	11
Khan Beigi (83)	2011	Semnan	1	34663	116	3.49	Respiratory system	-	-	12
Kouhestani (84)	2019	Tehran	1	600003	28	0.046	Urinary Tract	Escherichia coli	-	12
Izadi (85)	2020	Iran	972	107 669	28600	26.5	Urinary Tract	-	52	10
Hosseinpour (86)	2017	Shahrekord	1	48343	274	0.6	surgical site	Klebsiella	-	10
Omraninava (87)	2013	Mazandaran	1	625	28	4.5	Respiratory system	Escherichia coli	41.85	11

Data were analyzed using the Comprehensive Meta-Analysis software. Since each study reported the extent of hospital infection and sample size, variance for each study was calculated using a binomial

distribution. To synthesize findings from multiple studies, a weighted average was employed, with each study assigned a weight inversely proportional to its variance. Heterogeneity between studies was assessed using the I^2 index and Cochran's Q test. In this study, The I^2 index was equal to 90.33%, indicating substantial heterogeneity among the studies. For studies with high heterogeneity, a random-effects model was applied. The results were presented as pooled standardized scores with a 95% confidence interval along with a forest plot. Publication bias was evaluated visually using a funnel plot and objectively through Egger's linear regression test. Finally, Sensitivity analysis was also conducted to examine the influence of each study on the overall results.

Meta-regression was conducted to examine the association between the prevalence of hospital-acquired infections and study characteristics, including year of study, mean age of patients, and sample size, and to identify potential sources of heterogeneity among the included studies.

In the second phase, a modified two-step Delphi method was used from June to September 2024 to identify the most important and feasible strategies for reducing nosocomial infections. The Delphi method is a validated framework for consolidating expert insights and developing evidence-based consensus on complex clinical challenges. It employs structured iterative processes to systematically assess expert judgment and prioritize actionable recommendations within the field (23, 24). The adapted Delphi approach was selected due to its integration of an in-person discussion phase, which enhances collaborative expert engagement. While this method does not require unanimous consensus, it employs a predefined measurable agreement threshold to determine consensus. Additionally, it enables systematic evaluation and hierarchical organization of pre-existing evidence (25).

Following Dalkey and Helmer (26), expert panels typically include 10–50 members, depending on the research topic complexity. In this study, 15 experts from multiple Iranian provinces (Tehran, Sistan and Baluchestan, Isfahan, East Azerbaijan, Fars, Markazi, Semnan, Kerman, Gilan, Mazandaran, Hamadan, Kermanshah, Yazd, Razavi Khorasan, Lorestan, South Khorasan, Khuzestan, and Bushehr) were selected via email. Participants included hospital managers, physicians, nurses, healthcare staff, senior Ministry of Health officials, and faculty members from medical universities. Selection was based on publications, teaching experience, or professional experience related to nosocomial infections, with at least a master's degree required. Academic and professional résumés were reviewed to confirm expertise. Participants were free to decline, but all agreed to participate. Demographic characteristics are presented in Table 3.

Table 3. Characteristics of participants in the Delphi study

Variable	Frequency (%)
Gender	
Women	6 (40)
Men	9 (60)
Education Level	
PhD	11 (73.33)
Master's degree	4 (26.67)
Age	
>40	9 (60)
<40	6 (40)
Field of Study	
Healthcare Management	2 (13.33)
Medicine	5 (33.33)
Health policy	2 (13.33)
Nursing	5 (33.33)
Health economic	1 (6.68)
Work Experience	
Less than 10 years	6(40)
11-20	7 (46.67)
Over 20 years	2 (13.33)

The Delphi process consisted of two rounds. Round 1 involved developing a semi-structured questionnaire based on strategies identified through a literature review. To ensure clarity and content

validity, five experts in nursing, health economics, medicine, health policy, and health management reviewed the draft. Feedback was incorporated, resulting in a final questionnaire with 82 strategies, distributed via email on September 10, 2024. The questionnaire included three sections: (1) an introduction describing objectives and the scoring system, (2) participant demographics, and (3) tables of strategies. Each strategy was assessed using the FAME framework (Feasibility, Appropriateness, Meaningfulness, Effectiveness) on a 5-point Likert scale (1 = very low, 5 = very high). Experts could provide additional feedback or propose new strategies. Responses were collected within 10 days, with reminders sent as needed.

Round 2 was conducted as a one-hour, in-person meeting at Zabol School of Public Health for 4 experts, while 6 experts joined via video conference, and the remaining 5 experts participated asynchronously (via email or online survey) due to scheduling conflicts. The moderator explained the session's objectives, structure, and the evaluation process. Experts discussed the feasibility and importance of each strategy, provided rationales, and then individually rated all strategies using the same Likert scale. A consensus threshold of 70% agreement was applied: a strategy was considered agreed upon if at least 70% of experts rated it in the upper third of the scale (3.66–5). Strategies not meeting this threshold were excluded. Descriptive statistics were calculated using SPSS (version 24) for mean, standard deviation, and response frequency for each strategy. Following Round 1, anonymized feedback including total means and individual responses was shared with participants to guide revisions in Round 2. Only strategies meeting the consensus threshold and scoring in the upper third of the scale were included as viable interventions to reduce nosocomial infections.

Ethical Consideration

This mixed-methods study was approved by the Ethics Committee of Zabol University of Medical Sciences, Zabol, Iran (Ethical approval code: IR.ZBMU.REC.1397.190). The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The protocol

Results

Phase One: The prevalence of nosocomial infections in Iranian hospitals

A total of 22 studies conducted between 1999 and 2020 reported the prevalence of hospital-acquired infections in Iranian hospitals. Most studies (approximately 87.7%) used standardized questionnaires from the hospital infection surveillance system. The largest number of studies were conducted in Tehran, Qom, and Fars provinces, with most publications occurring in 2012, 2013, and 2017 (Figure 2).

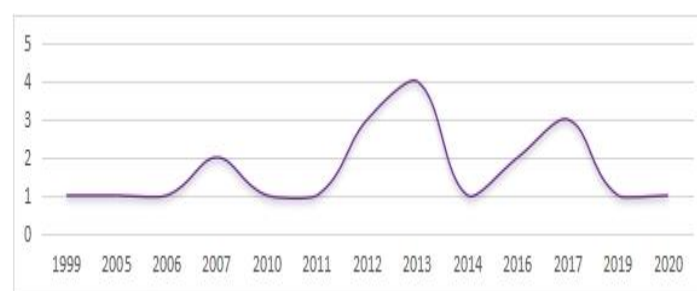


Figure 2: Frequency distribution of studies by year

The mean age of patients ranged from 31 to 41.85 years. The most commonly reported infections were urinary tract infections (40%), respiratory infections (34%), surgical site infections (13%), and bloodstream infections (13%). *Escherichia coli* was the most frequently identified microorganism. Also, 45,209 patients out of 2,908,335 were reported to have HAIs, corresponding to an overall prevalence ranging from 0.046% to 26.5%. Based on the pooled data of 22 studies, overall prevalence estimated via meta-analysis was 0.0001% (95% CI: 0.0001–0.0003) (Figure 3).

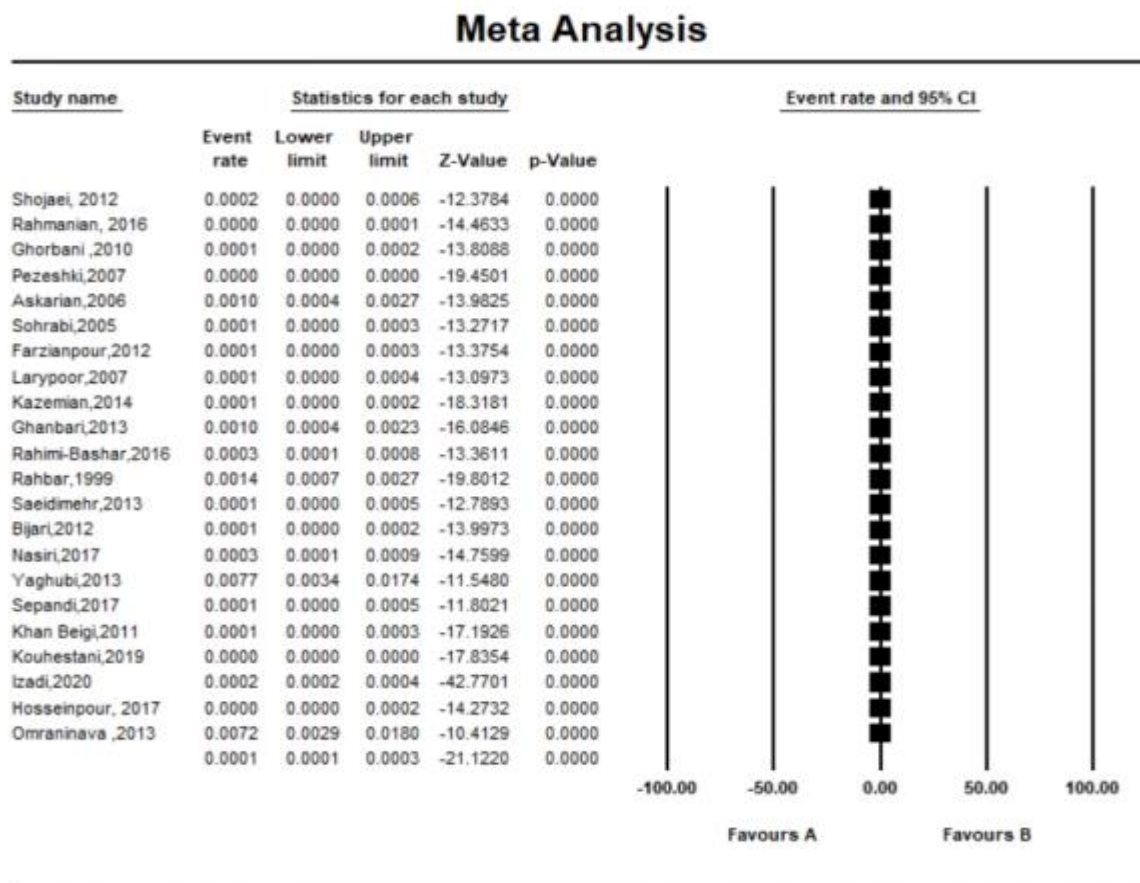


Figure 3: Meta-analysis of the overall prevalence of hospital-acquired infections in Iranian hospitals based on the random-effects model

Publication bias was assessed using Egger's test, which yielded a p-value of approximately 0.01, indicating a statistically significant likelihood of publication bias (Figure 4). In Figure 4, relative asymmetry of the primary study effects around the axis is observed. To address potential heterogeneity and publication bias, outlier or extreme effects were identified and eliminated through sensitivity analysis. Following sensitivity analysis, four studies exhibiting publication bias were excluded from the meta-analysis process (Figure 5). Upon exclusion of the aforementioned studies, the funnel plot after sensitivity analysis (Figure 5) demonstrated enhanced symmetry relative to Figure 4.

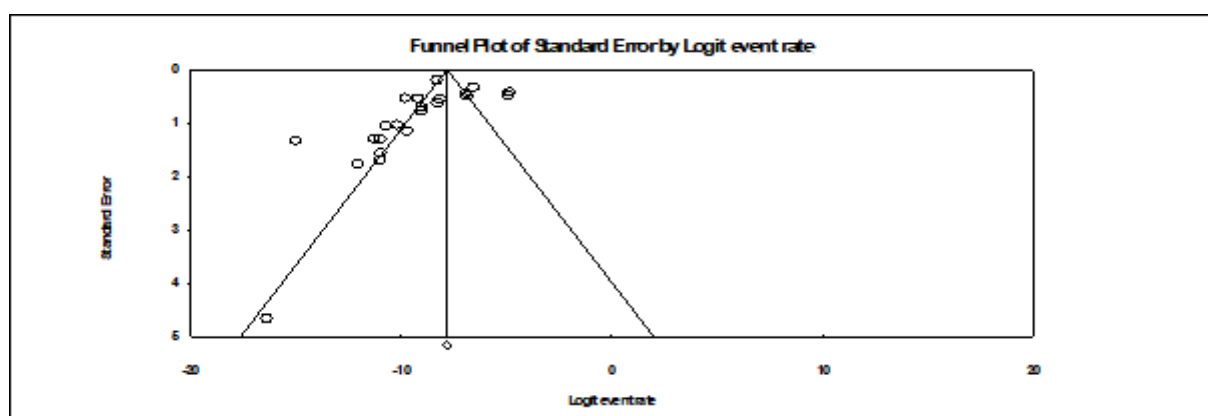


Figure 4: Publication bias detected via Egger's test prior to sensitivity analysis

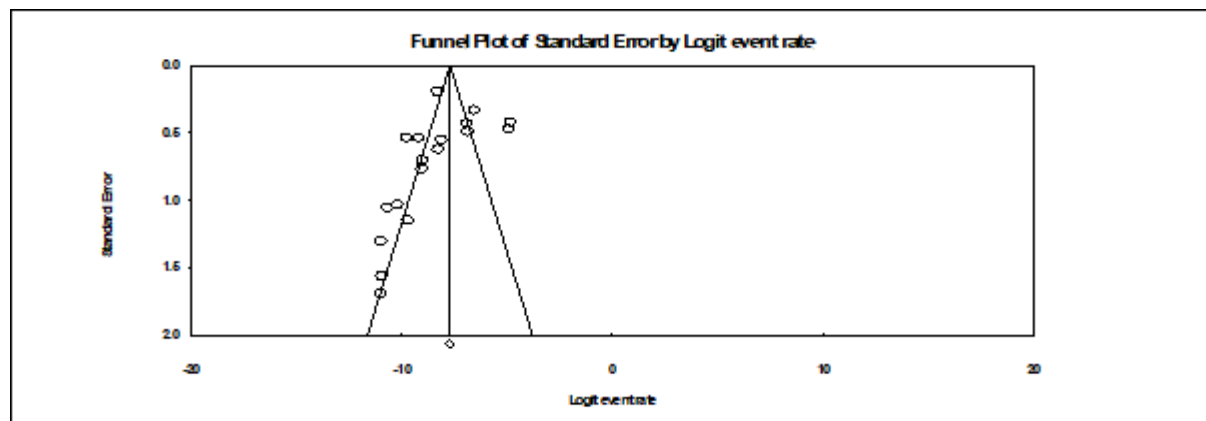


Figure 5: Publication bias detected via Egger's test following sensitivity analysis

Upon exclusion of the aforementioned studies, Funnel Plot No. 6 was generated, demonstrating enhanced symmetry relative to Funnel Plot No. 5. Furthermore, employing the Fail-Safe N Criterion (the number of hypothetical unpublished null studies required to nullify the observed significance threshold), incorporation of 16,697 non-significant effect sizes into the random-effects model meta-analysis rendered the pooled effect size non-significant. This resulted in the observed significance level escalating from $p=0.01$ to $p>0.05$ ($p=0.10$). Subsequent removal of outlying effect sizes yielded a final cohort of 18 studies (Table 4). Meta-regression analysis based on mean age, sample size, and study year showed significant associations with HAI prevalence ($P<0.05$) (Table 5).

Table 4: Meta-analysis of Hospital-Acquired Infection Prevalence in Hospitals Based on the Random-Effects Model Before and After Sensitivity Analysis

	Model	Number	Prevalence	Standard Error	Variance	Z	P-value
Before Sensitivity Analysis	Random	22	0.0001	1.58	2.52	-21.122	≤ 0.0001
After Sensitivity Analysis	Random	18	0.01	1.33	1.78	-19.67	≤ 0.0001

Table 5: Adjusted results of factors contributing to heterogeneity among studies (meta-regression model)

Variable	Correlation coefficient	P-value
Year	-0.07	≤ 0.01
Mean age	-0.02	≤ 0.01
Sample size	-0.02	≤ 0.01

The findings of Phase one identified specific infection types (urinary tract and respiratory infections), variations in prevalence across regions, and key factors associated with HAI occurrence. These results provided an evidence-based foundation for designing targeted interventions, highlighting the need for context-specific strategies that address the most prevalent and actionable risks in Iranian hospitals. This evidence directly informed Phase Two, where expert consensus was used to prioritize and operationalize intervention strategies.

Phase Two: Strategies to Reduce Hospital-Acquired Infection

The majority of participants in the study were male (60%), held doctoral degrees (73.33%), and were over 40 years old (60%). A significant proportion specialized in medicine and nursing (33.33%), while nearly half reported having 11–20 years of professional experience (46.67%).

The first round

After analyzing qualitative data and reviewing the literature, 82 strategies were identified to reduce Hospital-Acquired Infections. These strategies were grouped into six categories: 28 related to governance and leadership, 1 to financing, 22 to the health workforce, 16 to service delivery, 1 to health information systems, and 14 to medicines and equipment. These strategies were included in a first-round Delphi questionnaire sent to 15 experts.

The analysis of the first-round responses showed that 51 statements had mean scores within the acceptable range (3.66 to 5), while 11 statements fell into an indeterminate range (2.33 to 3.65). Additionally, 51 statements achieved over 70% agreement among the experts, indicating consensus. The consensus strategies included 14 related to governance and leadership, 1 to financing, 10 to the health workforce, 13 to service delivery, 1 to health information systems, and 12 to medicines and equipment. Since all 51 consensus strategies had acceptable mean scores, they were approved as effective for reducing HAIs and were removed from the second-round questionnaire.

The second round

In the second round of the Delphi process, statements that failed to reach consensus in the first round were further discussed during a face-to-face expert panel meeting. The second-round questionnaire consisted of eleven statements, including two related to governance and leadership, seven to the health workforce, and two to service delivery.

Analysis of the second-round responses demonstrated that five statements achieved a mean score within the consensus range (3.66–5), while two statements remained in the unclear range (2.33–3.65). Further evaluation based on response distribution indicated that five statements achieved more than 70% agreement among experts, thereby meeting the predefined consensus criterion (at least 10 experts providing homogeneous responses). Consequently, six statements were accepted in the second round, while two statements were excluded due to insufficient clarity and agreement. After integrating the findings from both Delphi rounds, a total of 56 context-specific strategies for reducing Hospital-Acquired Infections were finalized and approved. Unlike general infection control recommendations commonly reported in the literature, the accepted strategies were refined to emphasize operational details, feasibility within Iranian healthcare settings, and alignment with existing structural and resource constraints.

Notably, several high-ranked strategies required further specification to enhance their practical applicability. For example, developing evidence-based guidelines was operationalized as the development of localized infection prevention and control (IPC) guidelines derived from national surveillance data, hospital-level infection reports, and antimicrobial resistance patterns specific to Iranian clinical environments, rather than reliance on international guidelines alone.

Similarly, discharging patients as soon as possible was clarified as implementing standardized clinical discharge criteria and multidisciplinary discharge planning protocols aimed at minimizing unnecessary length of stay while ensuring patient safety and continuity of care. This strategy focuses on reducing exposure time to hospital pathogens without increasing readmission rates.

In addition, proper implementation of the hospital accreditation program was refined to emphasize active monitoring of IPC-related accreditation standards, routine internal audits, feedback mechanisms, and accountability at hospital and ward levels, rather than passive compliance with accreditation requirements.

Overall, the finalized strategies prioritize context-adapted, actionable, and measurable interventions that address real-world challenges in Iranian healthcare facilities. The emphasis on developing locally tailored IPC guidelines, grounded in existing data and expert consensus, ensures that the proposed strategies are not only theoretically sound but also practically applicable and responsive to the specific needs of clinical settings in Iran (Table 6).

To preserve clarity and readability, Table 6 presents concise, operationalized strategy labels, while detailed contextual explanations are provided in the Results section.

Table 6. Strategies to Reduce Hospital-Acquired Infection in Iran

Strategy	Feasibility (F)	Appropriateness (A)	Meaningfulness (M)	Effectiveness (E)	FAME Mean	Rank
Improving and monitoring hand hygiene compliance (proper washing techniques)	4.76	4.68	4.73	4.83	4.75	1
Ensuring proper ventilation in specialized care areas	4.72	4.63	4.70	4.71	4.69	2
Developing a comprehensive infection control training plan	4.65	4.58	4.53	4.54	4.58	3
Sterilizing bed sheets, dressings, and medical equipment	4.52	4.54	4.58	4.59	4.56	4
Establishing an Infection Prevention and Control Committee	4.59	4.58	4.55	4.52	4.56	5
Developing locally adapted, evidence-based infection control guidelines	4.53	4.54	4.55	4.55	4.54	6
Implementing standardized early discharge criteria for hospitalized patients	4.40	4.51	4.39	4.51	4.45	7
Strengthening implementation of infection control–related hospital accreditation standards	4.40	4.51	4.40	4.45	4.44	8
Ensuring the proper use of antibiotics	4.44	4.39	4.46	4.36	4.41	9
Utilizing respiratory physiotherapy for ventilator-dependent patients	4.42	4.37	4.46	4.29	4.38	10
Standardizing disinfection processes across the hospital	4.33	4.36	4.39	4.40	4.37	11
Increasing the number of microbiologists for laboratory diagnostic services	4.30	4.35	4.37	4.45	4.37	11
Changing infusion sets regularly to prevent contamination	4.32	4.34	4.41	4.40	4.37	11
Modeling successful hospital infection prevention programs	4.31	4.30	4.33	4.30	4.31	12
Developing treatment protocols for appropriate antibiotic use	4.28	4.34	4.32	4.30	4.31	12
Educating patients on infection prevention	4.29	4.28	4.32	4.34	4.31	12
Ensuring appropriate use of disinfectants and effective waste management	4.28	4.34	4.30	4.32	4.31	12
Using disposable endotracheal tubes to prevent infection	4.30	4.31	4.30	4.33	4.31	12
Empowering the Infection Control Committee with decision-making authority	4.23	4.27	4.22	4.28	4.25	13
Incentivizing adherence to infection control standards	4.25	4.26	4.23	4.27	4.25	13
Implementing precautionary measures for high-risk areas	4.26	4.23	4.22	4.30	4.25	13
Consulting infectious disease specialists for expert advice	4.19	4.18	4.22	4.16	4.19	14
Establishing a comprehensive hospital infection control program	4.18	4.17	4.18	4.19	4.18	15
Engaging with the media for public awareness of infection prevention	4.18	4.19	4.17	4.18	4.18	15
Providing ongoing training and education for healthcare personnel	4.19	4.18	4.17	4.18	4.18	15
Encouraging cooperation among relevant hospital departments	4.18	4.17	4.18	4.19	4.18	15
Utilizing effective sterilization methods for medical equipment	4.19	4.18	4.17	4.18	4.18	15
Using the smallest possible catheter size to reduce infection risks	4.19	4.18	4.17	4.18	4.18	15
Monitoring compliance through the Infection Control Committee	4.10	4.15	4.10	4.15	4.12	16
Establishing an Antibiotic Stewardship Program to optimize antibiotic use	4.10	4.10	4.15	4.15	4.12	16
Rewarding employees for good infection control practices	4.15	4.10	4.10	4.15	4.12	16
Ensuring compliance with standard precautions	4.15	4.15	4.05	4.15	4.12	16
Enhancing patients' immune defenses through medical interventions	4.10	4.10	4.15	4.15	4.12	16
Proper care of patients' skin and wounds to prevent infections	4.10	4.15	4.10	4.15	4.12	16
Controlling patient contact with contaminated surfaces	4.15	4.10	4.15	4.10	4.12	16
Ensuring appropriate isolation measures for high-risk patients	4.10	4.15	4.10	4.15	4.12	16
Increasing bed space to reduce overcrowding	4.15	4.10	4.15	4.10	4.12	16
Using chlorhexidine mouthwash for ventilated patients to reduce infection risks	4.15	4.15	4.05	4.15	4.12	16
Reducing intubation days and limiting use of central lines	4.00	4.05	4.05	4.10	4.06	17
Minimizing unnecessary laboratory testing that may cause skin damage	4.00	4.00	4.00	4.10	4.03	18
Celebrating Hand Hygiene Day to promote awareness	3.95	4.00	4.00	4.05	4.00	19
Improving interdisciplinary collaboration in infection control	4.00	4.00	4.00	4.00	4.00	19
Establishing and upgrading infection control units in emergency departments	4.00	4.00	4.00	4.00	4.00	19
Providing sufficient human resources for infection control	3.95	4.00	4.00	4.05	4.00	19
Involving all health team members in infection control efforts	4.00	4.00	4.00	4.00	4.00	19
Improving the nutritional status of patients to enhance immunity	4.00	4.00	4.00	4.00	4.00	19
Preventing accidental hand-to-needle contact to avoid contamination	4.00	4.00	4.00	4.00	4.00	19
Strengthening information and reporting systems for infection control	4.00	4.00	4.00	4.00	4.00	19
Ensuring the use of gloves and masks as standard precautions	3.90	3.95	3.90	3.95	3.93	20
Installing elbow-operated water taps to reduce hand contamination	3.90	3.95	3.90	3.95	3.93	20
Consulting infectious disease specialists for expert guidance	3.85	3.85	3.90	3.90	3.87	21
Providing sufficient motivation and support for infection control staff	3.85	3.85	3.90	3.90	3.87	21
Ensuring strict adherence to prescribed medication instructions, especially for antibiotics	3.85	3.85	3.90	3.90	3.87	21
Increasing financial resources to support infection control measures	3.80	3.80	3.80	3.85	3.81	22
Providing adequate physical infrastructure to support infection prevention	3.80	3.80	3.80	3.85	3.81	22
Developing incentive programs based on the performance of healthcare personnel	3.70	3.70	3.75	3.80	3.75	23

Discussion

This study aimed to determine the prevalence of hospital-acquired infections and identify context-specific strategies to reduce them in Iran. A total of 22 studies conducted between 1999 and 2020 reported HAI prevalence ranging from 0.046% to 26.5%. Based on a meta-analysis using a random-effects model, the pooled prevalence was estimated at 1%, which is substantially lower than the 8.8% reported by the World Health Organization for developing countries (27). The wide variation in reported prevalence may reflect differences in study design, sample size, reporting practices, and diagnostic criteria, as well as limited mandatory reporting and resource constraints in Iranian hospitals. Furthermore, the apparent low prevalence may be influenced by publication bias, as studies reporting high infection rates might be underrepresented in the literature. Comparisons with international data indicate that HAI prevalence in Iran is lower than estimates from high-income countries (7.6%) and other developing regions (9–15.5%) (27–29). These findings suggest that while reported HAI rates in Iran appear low, contextual factors, including underreporting and methodological heterogeneity, must be considered when interpreting the results.

In this study, *Escherichia coli* was identified as the most common microorganism causing hospital-acquired infections, followed by *Klebsiella*, *Pseudomonas*, and *Staphylococcus*. The predominance of *E. coli* may be related to its resistance to commonly used antibiotics. International evidence supports these findings, showing that *E. coli* is a leading cause of healthcare-associated infections, particularly urinary tract infections, and highlighting growing concerns about multidrug resistance (30, 31). For instance, analyses from the United States and global surveys indicate increasing resistance of *E. coli* isolates to fluoroquinolones and extended-spectrum cephalosporins, emphasizing its role as a high-priority pathogen in hospital antimicrobial resistance (30–32).

In this study, the urinary tract was identified as the most common site of hospital-acquired infection, followed by the respiratory tract. Urinary tract infections (UTIs) accounted for a significant proportion of HAIs in Iran, consistent with international evidence indicating that UTIs are the most prevalent type of hospital-acquired infection, often associated with catheter use. A recent epidemiological study in Iran reported that UTIs comprised 32.2% of all HAIs, particularly in intensive care units, highlighting the need for targeted interventions in high-risk wards (33–36).

Hospital-acquired respiratory infections, such as pneumonia, were the next most frequent, particularly among patients in intensive care units or those on mechanical ventilation. National and international data indicate that lower respiratory tract infections in hospitalized patients remain a major concern, with incidence rates ranging from 2.9% to 4.7% depending on patient population and setting (37, 38). These findings underscore the significant burden of HAIs on healthcare systems in Iran. Evidence suggests that 20–30% of HAIs are preventable through effective infection control measures (39). Therefore, allocating adequate human, financial, and physical resources is essential. International experience demonstrates that structured surveillance, monitoring, and targeted prevention programs can substantially reduce HAI incidence, which also decreases overall healthcare costs and improves patient safety (40).

Meta-regression analysis showed that study-level factors, including publication year, mean age of participants, and sample size, were significantly associated with the reported prevalence of hospital-acquired infections in Iranian hospitals ($P < 0.05$). The negative correlation coefficients indicate that more recent studies, studies with older patient populations, and those with larger sample sizes tended to report slightly lower HAI prevalence. This suggests that temporal improvements in infection control practices, differences in patient demographics, and methodological factors such as study size contribute to the variability observed across studies, highlighting the importance of considering these factors when interpreting pooled prevalence estimates.

In this study, the best strategies from experts' perspectives may include the following: hand hygiene compliance and proper handwashing techniques; proper ventilation for specialized care; developing a plan for infection control training; sterilization of bed sheets, dressing and other equipment; establishing an infection prevention and control committee; developing evidence-based guidelines; discharging patients as soon as possible and proper implementation of the accreditation program.

Hand hygiene compliance was highlighted as a critical factor in controlling hospital-acquired infections in the included studies. Observational data suggest that higher compliance rates—particularly above 80%—are associated with significant reductions in HAIs, whereas lower compliance is linked to higher infection rates (41, 42). Globally, the World Health Organization

estimates that up to 50% of avoidable HAIs could be prevented through effective hand hygiene programs, although average compliance varies widely between settings (43). Barriers such as workload, glove use, and limited access to handwashing facilities may reduce adherence, indicating that improving hand hygiene requires both behavioral interventions and systemic support (41, 43-45). These findings reinforce that hand hygiene remains a measurable and high-impact intervention for HAI reduction in Iranian hospitals, highlighting the need to integrate compliance monitoring into infection prevention strategies rather than focusing solely on broad educational guidance.

Proper ventilation was identified as an important factor in reducing hospital-acquired infections, particularly those transmitted via airborne or respiratory routes. Evidence from guidelines and observational studies indicates that well-designed ventilation systems—such as negative pressure isolation rooms, adequate air changes per hour, and controlled airflow—can reduce cross-contamination in critical hospital areas like ICUs, operating theaters, and isolation wards (46-48). These findings suggest that, in Iranian hospitals, attention to both mechanical and natural ventilation, alongside monitoring of airflow and environmental controls, is essential to mitigate respiratory HAIs, rather than relying solely on generalized recommendations.

Training healthcare staff is a key strategy for reducing hospital-acquired infections. Evidence from Iranian studies shows that structured in-hospital training programs significantly improve staff knowledge and compliance, resulting in measurable reductions in infection rates—for example, hand hygiene compliance increased by 20–22%, and nosocomial infections decreased from 0.7% to 0.5% (49, 50). Targeted training in high-risk areas such as ICUs and surgical units, along with patient and relative education, further enhances outcomes (51, 52). However, knowledge retention declines without periodic refresher courses, highlighting the necessity of continuous training, ongoing monitoring, and leadership support to ensure effective implementation. These findings emphasize that infection control interventions are most effective when combined with context-specific, sustained staff education and organizational reinforcement.

Effective sterilization and disinfection of hospital linens, dressings, and medical equipment is essential for preventing hospital-acquired infections. Evidence shows that adherence to established protocols, such as the Spaulding classification, significantly reduces infection risks (53). Critical items require sterilization, semi-critical items need high-level disinfection, and noncritical items like bed sheets usually require thermal or chemical laundering, except in high-risk scenarios. Proper cleaning before sterilization and staff training in handling and reprocessing are crucial to minimize cross-contamination. These findings highlight that the effectiveness of sterilization protocols depends not only on method selection but also on consistent implementation and compliance within the healthcare setting. Establishing an infection prevention and control (IPC) committee is a key strategy to reduce hospital-acquired infections. Evidence shows that functional IPC committees improve compliance with guidelines, enhance hand hygiene, and reduce multidrug-resistant infections (54, 55). Their effectiveness depends on clear roles, administrative support, interdisciplinary collaboration, and integration with staff training programs (56). Conversely, the absence of an active committee can lead to inconsistent practices due to workload pressures, staff turnover, and inadequate infrastructure. These findings highlight that the impact of IPC committees relies not just on their establishment, but on continuous monitoring, evaluation, and institutional commitment to sustain infection control improvements.

The Iranian National Committee for Hospital Infection Control was established in 2002. Iran's National Healthcare-Associated Infections Surveillance System was launched in 2006 with 100 hospitals, expanding to 555 hospitals by 2017. Pneumonia, bloodstream infections, urinary tract infections, surgical site infections, and infections associated with invasive devices are reportable under Iran's National Healthcare-Associated Infections Surveillance Program. The reported incidence rate of healthcare-associated infections within this system rose from 0.4% in 2007 to 1.3% in 2016, remaining below the expected incidence (57). This indicates incomplete reporting by hospitals and underscores the need for targeted interventions to improve compliance.

Developing evidence-based infection control guidelines requires integrating international best practices with local epidemiological data. Examples such as the UK's epic3 guidelines and CDC core practices highlight the importance of hand hygiene, environmental cleaning, device-associated infection protocols, and regular audits to reduce variation in practice (58, 59). However, translating guidelines into practice can be challenging due to contextual barriers and perceived gaps in evidence

(60). Iran's experience with underreported hospital-acquired infections underscores the need for locally tailored audits, staff training, and continuous monitoring. Combining structured frameworks with context-specific implementation ensures that guidelines remain actionable and effective in reducing infection rates (27).

Early discharge of patients, when clinically safe, is an effective strategy to reduce hospital-acquired infections, shorten hospital stays, and lower healthcare costs. Evidence shows that optimizing antibiotic use—such as earlier switch from intravenous to oral therapy or using outpatient parenteral antibiotic therapy (OPAT)—enables infectious disease specialists to safely discharge patients sooner without increasing readmissions (61, 62). This approach, particularly for infections like Acute Bacterial Skin and Skin Structure Infections (ABSSSI) and osteomyelitis, can free hospital beds, reduce total hospital days, decrease HAI incidence, and achieve significant cost savings, as demonstrated in studies from Greece, Italy, and Spain (63).

Proper implementation of hospital accreditation programs has been associated with reduced hospital-acquired infections (12, 64). Accreditation provides a structured framework that encourages hospital management and staff to adhere to evidence-based standards for quality and safety, including infection prevention and control measures (65). By institutionalizing these standards, accreditation fosters a culture of accountability and continuous improvement, which can translate into lower HAI rates. In the Iranian context, the effectiveness of accreditation likely depends on how rigorously hospitals integrate these standards into daily practices and monitor compliance.

Given the inherent limitations of any systematic review and meta-analysis, this study acknowledges several potential constraints. Firstly, significant heterogeneity ($I^2 = 90.33\%$) was observed across the included studies, necessitating the use of a random-effects model, which inherently provides a more conservative estimate. Secondly, the restriction to articles published in English and Persian may have introduced language bias, potentially overlooking relevant studies in other languages. Thirdly, variations in study designs, data collection methods, and diagnostic criteria for HAIs across different hospitals and regions in Iran may have contributed to the observed heterogeneity and may limit the generalizability of the pooled prevalence estimate. Finally, the reliance on published data means the study is susceptible to publication bias, wherein studies with statistically significant or positive findings are more likely to be published, potentially overestimating the true prevalence of HAIs in Iranian hospitals.

Implications for practice

This mixed-methods study, combining a systematic review/meta-analysis with insights from expert interviews, provides a comprehensive understanding of HAIs in Iranian hospitals. The meta-analysis revealed a substantial pooled prevalence of HAIs, highlighting a critical public health challenge. High heterogeneity across studies underscores the complex interplay of local factors influencing infection rates. Concurrently, expert interviews identified key strategies for mitigating HAIs in Iran, including strengthening surveillance systems, enhancing infection control infrastructure, promoting education and training, implementing antimicrobial stewardship programs, and fostering a culture of patient safety. Integrating these findings, we recommend a multi-faceted policy approach for Iranian healthcare decision-makers. This includes investments in national surveillance using standardized protocols to monitor infection rates; robust infection control programs within hospitals, emphasizing prevention bundles; comprehensive healthcare worker education; antimicrobial stewardship; and cultivating a hospital-wide safety culture that empowers reporting and proactive participation in quality improvement. Prioritizing these coordinated strategies promises to significantly reduce the burden of HAIs, improve patient outcomes, and optimize resource utilization within the Iranian healthcare system. Future research should focus on implementing and evaluating specific HAI prevention measures tailored to the Iranian healthcare context, leveraging the synergy between quantitative data and qualitative expert insights.

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Conflicts of interest

The authors declare that they have no competing interests.

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Authors' Contributions

M.A and P.I participated in the design of the study. P.I, V.E, M.S.H, M.P.M and M.S undertook the literature review process. All authors drafted the manuscript. All authors read and approved the final manuscript.

Artificial Intelligence statement

The authors used an artificial intelligence-based language model (ChatGPT) to improve the clarity, grammar, and structure of the manuscript.

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