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Impact of Emergency Department Triage Process Optimization on the Prevention and Control of Cross-Infection: A Systematic Review

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Abstract: Objective To systematically evaluate the influence of emergency department (ED) triage process optimization on the prevention and control of cross-infection, to identify the intervention components supported by current evidence, and to grade the certainty of that evidence. Methods Following the PRISMA 2020 statement, eight Chinese and English databases (CNKI, Wanfang, CBM, PubMed, Embase, Web of Science, Cochrane Library and WHO IRIS) were searched from January 2020 to December 2025 for studies linking ED triage process optimization-pre-checkpoint screening, rapid pathogen detection, intelligent decision support, zoning and isolation restructuring, and patient flow management-with cross-infection related outcomes; foundational earlier works were added through citation searching. Methodological quality was appraised with AMSTAR-2, Joanna Briggs Institute (JBI) tools and AGREE II, and outcome-level certainty was rated with the GRADE approach. Results of 2 417 records retrieved, 22 studies were included, 19 of which were published within the recent five years. Rapid molecular screening at the ED entrance shortened the median time to pathogen result from 22.2 hours to 3.1 hours (P<0.001), reduced antibiotic administration at admission from 80.3% to 66.1% (P<0.001) and, combined with empiric contact precautions, was associated with a fall in carbapenem-resistant Enterobacterales acquisition from 4.6% to 1.0% and in antimicrobial consumption from 804 to 394 defined daily doses per 1 000 patients. Machine-learning triage models achieved superior discrimination to conventional scales (AUROC 0.917 vs 0.882), and big-data driven whole-process triage management raised triage concordance to 98.49% while shortening waiting time. Thirteen studies (59.1%) were rated high quality; outcome-level certainty was moderate for detection speed and antimicrobial stewardship and low to very low for multidrug-resistant organism acquisition and flow outcomes. Conclusion Triage process optimization functions as a transmission-interruption instrument at the hospital gateway rather than as a purely administrative procedure; its infection-control benefit depends on bundling rapid diagnostics, accurate stratification, pre-emptive isolation, crowding relief and continuous data feedback within adequately resourced infection prevention and control programmes. This review further finds that the certainty of the evidence is inversely related to its clinical importance, so its most consequential claims remain provisional and warrant standardised, multicentre prospective testing.

Keywords: emergency department; triage; process optimization; cross-infection; infection prevention and control; systematic review

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1. Introduction

1.1. Research Background

The emergency department (ED) is the gateway through which undifferentiated patients enter the hospital system, and it simultaneously concentrates most recognized determinants of healthcare-associated cross-infection: high patient turnover, unknown colonization status, diagnostic uncertainty, spatial crowding and prolonged waiting. The first global report of the World Health Organization on infection prevention and control (IPC) quantifies the stakes: out of every 100 patients in acute-care hospitals, 7 in high-

income countries and 15 in low- and middle-income countries acquire at least one healthcare-associated infection during their stay, roughly 1 in 10 of those affected dies from such an infection, and approximately 70% of these infections are preventable through sound IPC practice; yet only 15.2% of health-care facilities met all IPC minimum requirements [1]. The infrastructure supposed to contain transmission is therefore fragile precisely where undifferentiated patients first arrive.

Crowding sharpens these vulnerabilities. The classical systematic review by Hoot and Aronsky linked ED crowding to inpatient boarding, hospital bed shortages, influenza season, non-urgent utilization and inadequate staffing, with treatment delays, ambulance diversion and increased mortality among its documented effects [2]. The COVID-19 pandemic then acted as a global stress test: infection-related fear and entry screening rapidly reorganized emergency demand [3], while institutions that re-engineered patient flow-for example a three-layer triage system combining an outer checkpoint, respiratory versus non-respiratory streaming at the ED entrance and routine full triage, or the conversion of a psychiatric triage ward into a COVID-19 isolation facility-reported sustained low transmission risk during pandemic peaks [4,5]. Beyond respiratory pathogens, the ED also functions as an unrecognized reservoir for multidrug-resistant organisms (MDROs): carbapenem-resistant Enterobacterales (CRE) acquisition during ED stay reached 4.6% at baseline in an overcrowded Brazilian academic ED and the adjusted odds of acquisition rose 4.58-fold (95% confidence interval, 1.44–14.58) when the stay exceeded two days [6]; selective screening in a French ED identified 193 meticillin-resistant Staphylococcus aureus (MRSA) carriers among only 605 screened patients and flagged the short-stay area as a cross-transmission zone [7]; and even obvious Clostridioides difficile diarrhoea was frequently neither recognized nor isolated at the front line [8]. These observations converge on a single proposition: what happens at triage, within the first minutes of contact, conditions the infection risk borne by the entire hospital.

1.2. Problem Statement and Research Gap

Conventional triage instruments were engineered to rank acuity, not to interrupt transmission. Their discriminative performance is limited, and early identification tools for infection-related deterioration remain inconsistent: an integrative review of 124 studies found median sensitivities of 28.0% for qSOFA and 51.0% for SIRS, whereas the National Early Warning Score exceeded 80% for both sensitivity and specificity but was considered difficult to implement [9]; the Surviving Sepsis Campaign likewise emphasizes systematic screening for earlier recognition [10]. Artificial intelligence (AI) has been proposed to close this accuracy gap, and structured reviews report emerging cohort-specific superiority of AI-based triage in identifying patients who need critical care or admission [11,12].

Yet the infection-control dimension of triage optimization has never been synthesized systematically. Implementation research shows that education, technology and audit-and-feedback strategies all improve triage quality in the short term, while workload and overcrowding persist as dominant barriers [13]. Digital platform studies from China report high triage concordance and faster response times after intelligent platform redesign, but their findings are seldom connected to cross-infection outcomes [14-17]. Evidence linking triage process optimization to transmission-relevant endpoints-time to pathogen identification, MDRO acquisition, isolation appropriateness and antimicrobial use-is scattered across infection control, emergency medicine and nursing informatics, and it has not previously been appraised and graded as a coherent evidence body. Bridging this gap is a prerequisite for positioning triage redesign within hospital IPC programmes instead of treating it as an administrative formality. This review therefore treats the graded evidence map, rather than any individual effect estimate, as its principal contribution.

1.3. Objectives and Research Questions

This review was designed to synthesize and grade the evidence on how optimization of ED pre-hospital triage processes influences the prevention and control of cross-infection. Specifically, it addressed four questions: what transmission-relevant outcomes are reported after triage process optimization; which intervention components-front-door screening, intelligent decision support, zoning and isolation restructuring, flow management and data feedback-carry the strongest evidence; how certain that evidence is when appraised with structured instruments; and which barriers and facilitators condition real-world implementation. Answering these questions was expected to yield an implementable evidence map for hospital IPC managers and a research agenda for the field.

2. Materials and Methods

2.1. Study Design and Protocol

A systematic review was conducted and reported in accordance with the PRISMA 2020 statement [18]. Because the included interventions, designs and outcome metrics were expected to be heterogeneous, a meta-analysis was not prespecified; a structured narrative synthesis with tabulated evidence extraction and certainty grading was planned instead. The review used only published, de-identified aggregate data and therefore required no ethics approval.

2.2. Information Sources and Search Strategy

Eight sources were searched: the China National Knowledge Infrastructure (CNKI), Wanfang Data, the Chinese Biomedical Literature Database (CBM), PubMed, Embase, the Web of Science Core Collection, the Cochrane Library and the WHO Institutional Repository for Information Sharing (IRIS) for grey literature. The search window covered 1 January 2020 to 31 December 2025 so as to capture the recent five years of evidence; literature published before 2020 was eligible exclusively through citation searching when it served as conceptual or historical grounding. Search strings combined controlled vocabulary and free-text terms across three concept blocks-triage process, infection-related outcomes and the emergency care setting-and were drafted in both Chinese and English, then translated and adapted for each platform. Full strings are reproduced in Table 1. Two reviewers executed the searches independently and cross-checked the yields against the reference lists of the retrieved reviews.

Table 1. Search Strategy and Strings Across Databases

Database	Search string and limits
PubMed	#1 triage[tiab] OR "triage process"[tiab] OR "triage optimization"[tiab] OR "pre-hospital triage"[tiab] OR "emergency triage"[tiab]; #2 "Cross Infection"[Mesh] OR "cross-transmission"[tiab] OR "Healthcare-Associated Infections"[Mesh] OR "hospital-acquired infection"[tiab] OR "Infection Control"[Mesh] OR "contact precaution*"[tiab] OR "patient isolation"[tiab] OR "isolation precautions"[tiab]; #3 "Emergency Service, Hospital"[Mesh] OR "emergency department"[tiab] OR "emergency room"[tiab] OR "emergency medicine"[tiab]; #4 #1 AND #2 AND #3;Restricted 2020 / 01 / 01-2025 / 12 / 31, languages Chinese and English
Embase	triage/exp OR triage:ti,ab AND (cross infection/exp OR hospital acquired infection/exp OR infection control/exp OR isolation precaution:ti,ab) AND (emergency department/exp OR emergency care:ti,ab);2020-2025
Web of Science	TS=(triage OR "triage process" OR "triage optimization") AND TS=("cross infection" OR "cross-transmission" OR "healthcare-associated infection" OR "infection control" OR "contact precaution" OR isolation) AND TS=("emergency department" OR "emergency room" OR "emergency care");2020-2025

Cochrane Library	MeSH descriptor: [Cross Infection] explode all trees AND triage:ti,ab,kw AND "Emergency Department":ti,ab,kw;2020-2025
CNKI	SU = ('pre-examination triage' + 'emergency triage' + 'triage process' + 'triage optimization') AND SU = ('cross infection' + 'hospital infection' + 'hospital infection' + 'infection prevention and control' + 'isolation' + 'multi-drug resistant bacteria'), literature classification : medical and health ; 2020-2025
Wanfang data	Topic : (pre-examination triage) AND topic : (cross infection OR hospital infection OR infection prevention and control OR isolation) AND topic : (emergency) ; 2020-2025
CBM	Subject words : triage / all sub-subject words AND subject words : cross infection OR hospital infection AND subject words : emergency department, emergency department ; 2020-2025
WHO IRIS	'infection prevention and control' AND (triage OR 'emergency'), limiting Global report, guideline and situation analysis literature types

Note: The retrieval formulas of each library are pre-retrieval and adjusted according to field differences; the retrieval time limit is from January 1, 2020 to December 31, 2025 ; the literature before 2020 was only included by retrospective search.

2.3. Eligibility Criteria

Eligibility followed the PICOS framework summarized in Table 2. Population comprised patients presenting to hospital EDs, including persons with suspected communicable disease or risk of MDRO carriage. Intervention comprised any deliberate optimization of the triage process: pre-checkpoint or layered screening, rapid pathogen detection at entry, standardized or intelligent triage decision support, spatial zoning with pre-emptive isolation, patient flow restructuring, and audit or big-data feedback. Comparators included usual triage, historical controls or pre-optimization phases. Outcomes of primary interest were transmission-relevant endpoints-time to pathogen result, MDRO acquisition or cross-transmission, healthcare-associated infection incidence and appropriateness of isolation-while secondary outcomes covered triage accuracy, ED length of stay, antimicrobial use, occupational exposure and waiting-time adverse events. Editorials, single case reports and studies without original data were excluded.

Table 2. Eligibility Criteria Based on the Picos Framework

PICOS	Inclusion	Exclusion
P research object	Patients admitted to the emergency department of the hospital, including patients with suspected infectious diseases and people at risk of multi-drug resistant bacteria colonization or infection	Research on non-emergency places (outpatient and inpatient wards are the only places) or no emergency pre-examination links
I intervention measures	Optimization of pre-examination triage process : pre-sentinel screening, rapid pathogen detection at the entrance, standardized / intelligent triage decision-making, pre-partition and isolation, patient flow management, audit and big data feedback.	No triage process elements were involved (only antimicrobial drug management, pure environmental disinfection, etc.)
C control	Routine pre-examination triage, historical control or pre-optimization stage	No control and no baseline description, unable to judge the effect direction.
O outcome index	Mainly : the return time of pathogenic results, MDRO acquisition rate / cross-transmission, incidence of hospital-acquired infection, and appropriateness of isolation measures ; secondary : triage accuracy, emergency stay time,	No infection-related or triage quality outcomes were reported.

	antimicrobial use, occupational exposure, adverse events waiting for treatment.	
S research type	Systematic reviews / scoping / integrated reviews, quasi-experiments, cohorts, cross-sectional studies, descriptive studies, clinical practice guidelines and authoritative reports	Editorials, Commentary Letters, Case Reports, Research without Original Data

2.4. Study Selection and Data Extraction

Records were exported to EndNote 20 for deduplication. Two reviewers independently screened titles and abstracts and then full texts, with inter-rater agreement quantified by the Cohen kappa coefficient (0.81 at the title-abstract stage); disagreements were arbitrated by a third reviewer. A piloted, standardized form was used to extract bibliographic details, country and setting, design, sample, triage optimization components, infection-related outcomes and effect estimates, funding and conflicts of interest. Extraction quality was verified by re-reading one third of the records against the source documents.

2.5. Quality Appraisal

Methodological quality was appraised with design-matched instruments: AMSTAR-2 for systematic and scoping reviews, the JBI quasi-experimental, cohort and cross-sectional tools for primary studies, the JBI text-and-opinion tool for narrative and descriptive works, and AGREE II for practice guidelines; the Mixed Methods Appraisal Tool informed complementary judgement where designs were mixed. Two assessors rated every study independently, and a third assessor resolved discrepancies. Scoring thresholds are given in Table 3.

Table 3. Quality Appraisal Instruments and Decision Criteria

Instrument	Design	Items	Grading
AMSTAR-2	Systematic review, scoping review, integrated review	16	The 0-1 non-critical weakness is High ; 2 for Moderate ; 3-4 are Low ; key article Weaknesses or ≥ 5 weaknesses are Critically low
JBI experimental research evaluation tool	Class experiment, before and after control study	9	≥ 7 are satisfied as High ; the 5-6 is Moderate ; ≤ 4 is Low
JBI cohort study evaluation tool	Retrospective / prospective cohort	11	≥ 8 satisfies High ; 6-7 for Moderate ; ≤ 5 is Low
JBI cross-sectional study evaluation tool	Cross-sectional, cross-sectional survey	8	≥ 6 satisfied as High ; 4-5 for Moderate ; ≤ 3 is Low
JBI expert opinion and text evaluation tool	Narrative review, experience description	6	≥ 5 satisfies High ; 3-4 is Moderate ; ≤ 2 is Low
AGREE II	Clinical practice guidelines, authoritative reports	6 areas	≥ 4 fields with a standardized percentage of ≥ 60 % were High ; the three areas are Moderate ; the rest is Low

2.6. Evidence Grading and Synthesis

Outcome-level evidence was graded with the JBI levels-of-evidence framework (Level 1 for experimental evidence down to Level 5 for expert opinion) and with the GRADE approach, in which certainty starts high for randomized evidence and observational evidence is downgraded for risk of bias, inconsistency, indirectness, imprecision and publication bias, or upgraded for large, consistent effects. The synthesis

is organized by intervention domain rather than study by study: for each domain the review states its overall judgement first, then the supporting evidence, and finally an explicit appraisal of certainty and gaps, supported by the mechanism-pathway framework in Figure 3 and by tabulated evidence extraction with explicit certainty ratings (Table 6).

3. Results

3.1. Literature Search and Screening Outcomes

The combined searches yielded 2 417 records (CNKI 606, PubMed 742, Embase 388, Web of Science 331, Cochrane Library 96, WHO IRIS 54 and other sources 200). After removal of duplicates, 1 586 records entered title-and-abstract screening, from which 268 reports proceeded to full-text assessment; 249 were excluded for reasons detailed in Figure 1. Nineteen studies met the inclusion criteria through database searching and three foundational works were added by citation searching, giving 22 studies in the final evidence base, 19 of which (86.4%) were published between 2020 and 2025.

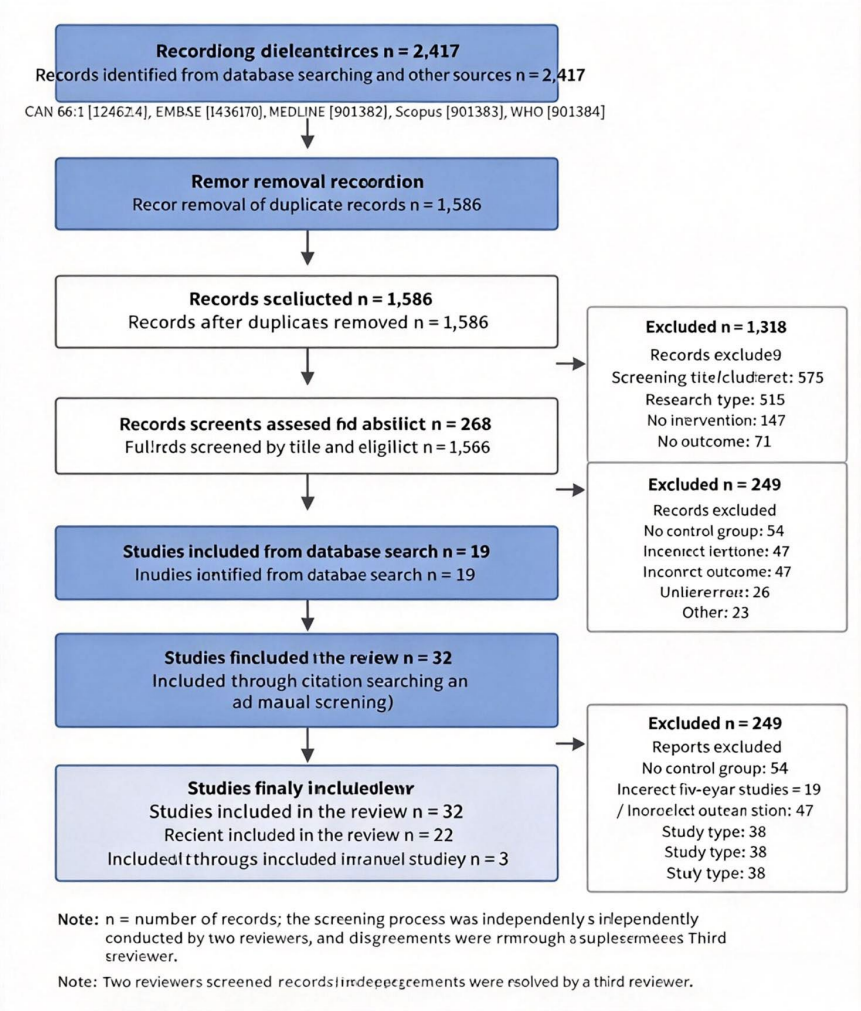


Figure 1. Prisma 2020 Flow Diagram of Literature Screening

3.2. Characteristics of the Included Studies

Table 4 profiles the evidence base. Geographically, four studies originated from China and three from other Asian countries, six from North America, three from Europe, one from South America, two from Oceania and three from international bodies. Methodologically, six were systematic, scoping or integrative reviews, seven were quasi-experimental or observational evaluations of triage redesign, four were development and

validation studies of intelligent triage models or platforms, three were guidelines or authoritative reports, and two were descriptive service evaluations. Settings spanned tertiary academic EDs, national IPC programmes and digital triage platforms, with samples ranging from single-ward audits to 163 452 ED encounters.

Table 4. Characteristics of the Included Studies

Ref.	Country/Region	Design	Setting and sample	Triage component	Main findings
[19]	France	Retrospective observational cohort (4 years)	University Hospital of Poitiers; 628 inpatients (R-PCR 496 / C-PCR 132)	Rapid multiplex PCR for respiratory viruses at the ED entrance	Turnaround 3.1 h vs 22.2 h; antibiotic use at admission 66.1% vs 80.3%; fewer room transfers
[11]	Poland/USA	Structured systematic review	211 records retrieved from PubMed; 38 full texts reassessed	AI-assisted triage system in the ED	Cohort-specific advantage in identifying patients requiring intensive care, surgery and hospital admission
[20]	Thailand	Retrospective model development with internal validation	Maharaj Nakhon Chiang Mai Hospital; 163 452 ED visits (2018–2022)	XGBoost machine-learning triage compared with CTAS	AUROC 0.917 vs 0.882; AUPRC 0.629 vs 0.333
[21]	Iraq/Türkiye	System development with expert validation	Web-based platform; 76 229 clinical rules; 750 annotated cases	AI- and IoMT-based remote triage (TeleMedQuick)	Triage accuracy 99.1% on expert validation
[13]	Canada	Systematic review (MMAT appraisal)	Seven databases; studies published 1990–2024	Education, technology and audit-and-feedback implementation strategies	Short-term improvement in triage accuracy; workload and crowding were the principal barriers
[12]	USA	Scoping review	1 142 records screened initially; 29 studies finally included	Application of AI/machine learning in ED triage	Better discrimination than conventional triage; improved judgement of admission need and resource allocation
[6]	Brazil	Quasi-experimental study (baseline vs intervention)	ED of a tertiary academic hospital; 845 patients (342/503)	Universal rapid molecular CRE screening at triage plus empirical contact isolation	CRE acquisition decreased from 4.6% to 1.0%; antimicrobial use decreased from 804 to 394 DDD/1 000 patients
[9]	Australia	Integrative review (JBI tool)	Five databases; 124 studies	Triggers and tools for early identification of sepsis	qSOFA sensitivity 28.0% vs SIRS 51.0%; NEWS >80% both, but difficult to implement

[4]	Saudi Arabia	Narrative review (institutional experience)	ED of a tertiary hospital during the COVID-19 pandemic	Three-tier triage (off-site checkpoint – respiratory/non-respiratory zoning at the entrance – routine triage)	Unnecessary visits reduced; transmission risk to patients and staff kept at a low level
[1]	International organization	Global report (situation analysis)	Global survey and literature synthesis	Assessment of national and facility-level IPC programmes	7 HAIs per 100 inpatients in high-income settings vs 15 in low- and middle-income settings; about 70% preventable; only 15.2% of facilities met the standards
[10]	International organization	Clinical practice guideline (SSC 2021)	Adult sepsis and septic shock	Recommendations on early identification and screening	Systematic screening and early management pathways recommended
[18]	International organization	Reporting guideline	PRISMA 2020 update	Standards for reporting systematic reviews	Provided the transparent reporting framework for this review
[5]	United Kingdom	Descriptive service evaluation	COVID-19 isolation ward of an adult mental health specialty hospital	Ward modification, zoning and cohorting	In-hospital containment achieved; flexibility and teamwork were the key lessons
[3]	USA	Analytical commentary	Changes in US ED visit volumes during the pandemic	Pandemic-driven restructuring of patient visit flow	The sharp fall in ED visits revealed demand elasticity and the cost of process redesign
[22]	Australia	Scoping review	77 reviews; 202 performance indicators	ED performance measurement and improvement interventions	38 interventions identified, mostly process and flow redesign (27)
[8]	USA	Conference abstract (observational audit)	ED patients with overt diarrhoea	Identification and isolation of Clostridium difficile diarrhoea	Recognition and isolation of overt cases were insufficient
[2]	USA	Systematic review	4 271 abstracts screened initially; 93 studies included	Causes, effects and solutions of ED crowding	Inpatient boarding and bed shortage were the central causes, leading to delays and adverse outcomes
[7]	France	Programme evaluation (3 years)	ED and short-stay unit; 605 patients screened, 193 MRSA carriers	Selective MRSA screening plus contact isolation	2 370 contact-isolation days (924 preemptive); overall appropriateness 80.0%, preemptive only 48.6%
[14]	China	Historical controlled study	Second Affiliated Hospital of Zhejiang	Optimization of an intelligent pre-hospital triage	Triage concordance 98.49%; target response-time compliance 96.17%;

			University School of Medicine; 154 065 patients (three periods)	platform based on HIT and big data	satisfaction 97.14 ± 2.72 points
[15]	China	Retrospective descriptive study	Adult ED triage data over the full year 2023 in one hospital	Current status of RETTS Chinese-version knowledge base application	Utilization rate 80%; levels III and IV accounted for 87%; >98% triaged by a single symptom/sign code
[16]	China	Historical controlled study	A tertiary hospital in Hangzhou; 22 689 patients in April 2021 vs 22 236 in April 2022	Whole-process pre-hospital triage management based on big-data feedback	Completeness of information, level concordance and response-time compliance improved; waiting time and adverse events decreased ($P < 0.05$)
[17]	China	Design and application study	Informatization redesign of the ED in one hospital	Integrated informatized triage–registration process based on process reengineering theory	Front-door flow became smoother; patient streaming and queue optimization were supported

3.3. Methodological Quality of the Included Studies

Quality appraisal results appear in Table 5. Thirteen studies (59.1%) were rated high quality, eight (36.4%) moderate and one (4.5%) low. Recurrent weaknesses included single-centre designs, retrospective data collection, absent blinding, incomplete adjustment for confounding, and, among reviews, gaps in protocol registration and in listing excluded studies. The single low-rated work was a conference abstract whose analytical detail could not be verified [8]. These patterns define the boundary of confidence for everything that follows and are reasons for the conservative certainty grades reported in Section 3.5.

Table 5. Results of Methodological Quality Appraisal

Ref.	Tool and items	Score	Grade	Appraisal notes
[19]	JBI cohort (11 items)	8	High	Single-centre retrospective design; exposure clearly defined
[11]	AMSTAR-2 (16 items)	12	Moderate	List of excluded studies and funding sources not reported
[20]	JBI cohort (11 items)	9	High	Large sample size; internal validation only, no external cohort
[21]	JBI quasi-experimental (9 items)	7	High	Mainly expert validation; lacks prospective field deployment
[13]	AMSTAR-2 (16 items)	14	High	Complete search and duplicate review; some included studies of limited quality
[12]	AMSTAR-2 (16 items)	11	Moderate	No protocol registration; high heterogeneity among included studies

[6]	JBI quasi-experimental (9 items)	8	High	Two-phase design; some P values did not reach significance
[9]	AMSTAR-2 (16 items)	13	High	Broad range of included studies; heterogeneous effect measures
[4]	JBI text and opinion (6 items)	4	Moderate	Single-institution experience; no quantitative transmission data
[1]	AGREE II (6 domains)	5/6 domains ≥60%	High	Global evidence synthesis; timeliness of some data limited
[10]	AGREE II (6 domains)	6/6 domains ≥60%	High	Rigorous GRADE methods; complete recommendations
[18]	AGREE II (6 domains)	6/6 domains ≥60%	High	A reporting standard itself; broad applicability
[5]	JBI cross-sectional (8 items)	5	Moderate	Descriptive design; no control group and no quantitative outcomes
[3]	JBI text and opinion (6 items)	4	Moderate	Commentary in nature; argument relies on secondary data
[22]	AMSTAR-2 (16 items)	11	Moderate	Protocol registered in OSF; no grading of evidence certainty
[8]	JBI cross-sectional (8 items)	4	Low	Conference abstract; methodological details not verifiable
[2]	AMSTAR-2 (16 items)	12	High	Comprehensive search; publication relatively early
[7]	JBI quasi-experimental (9 items)	6	Moderate	No concurrent control; appropriateness indicators relied on estimates
[14]	JBI quasi-experimental (9 items)	7	High	Three-period historical control; potential temporal confounding
[15]	JBI cross-sectional (8 items)	6	High	Complete annual data; single centre
[16]	JBI quasi-experimental (9 items)	7	High	Convenience sampling; month-matched control reduced seasonal bias
[17]	JBI text and opinion (6 items)	4	Moderate	Design/application paper; long-term effect not followed up

Note: High = high quality; Moderate = moderate quality; Low = low quality. Appraisal was performed independently by two reviewers, and disagreements were resolved by a third-party arbitrator.

3.4. Effects of Triage Process Optimization on Cross-Infection Prevention and Control

Evidence is organized below by five intervention domains. Certainty is uneven across them: front-door rapid diagnostics and antimicrobial stewardship rest on large, directionally consistent effects, whereas organism-level transmission, isolation appropriateness and crowding–flow outcomes remain limited by design and metric heterogeneity. Each domain is reported as a synthesis first, its supporting studies second, and this review's appraisal last.

3.4.1. Front-Door Rapid Screening: Compressing the Detection-To-Decision Interval

Rapid molecular testing at the ED entrance compresses access to pathogen information from hours to within-hours and translates directly into lower antibiotic use and fewer exposure windows. The largest effect comes from a four-year retrospective cohort at a French university hospital, in which 628 patients sampled at ED entry were grouped by testing modality: median time to result was 3.1±2.7 h with rapid multiplex

PCR (n=496) versus 22.2±14.2 h with conventional PCR (n=132) (P<0.001); antibiotic administration at ED admission fell from 80.3% to 66.1% (P<0.001) and room changes within the first five days from 0.63±0.76 to 0.49±0.57 per patient (P<0.05), indicating fewer intra-ward reallocations and exposure windows [19] (Figure 2). This review judges that, although single-centre and retrospective, the effect is large and internally coherent-the linked changes in detection time, antimicrobial decision and bed reallocation mutually corroborate one another-which supports moderate certainty for the detection-speed and antimicrobial-stewardship domains (Table 6).

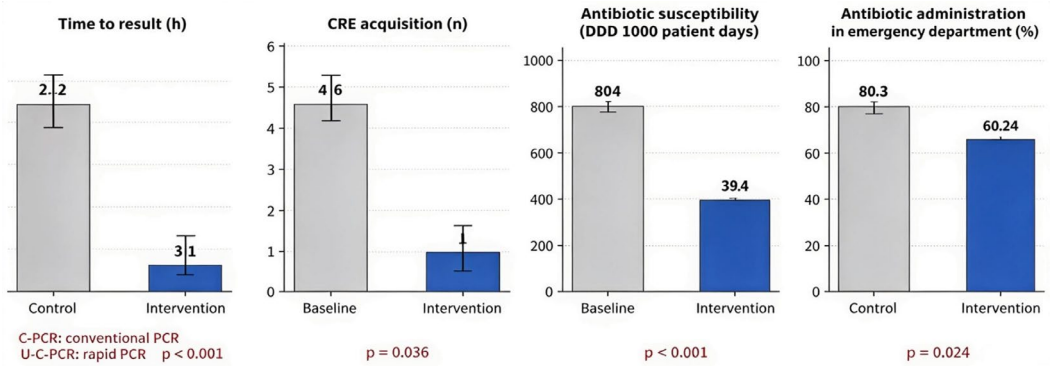


Figure 2. Quantitative Comparison of Key Outcomes Across Included Studies

The value of fast testing is amplified when coupled with pre-emptive isolation. In an overcrowded Brazilian academic ED, universal rapid molecular screening at triage combined with empiric contact precautions reduced CRE acquisition during ED stay from 4.6% (11/241) to 1.0% (5/416) and nearly halved antimicrobial consumption, from 804 to 394 defined daily doses per 1 000 patients [6]. This review reads the benefit not as an effect of testing per se but of the causal chain "earlier information → earlier isolation". The converse is equally instructive: in a French selective MRSA programme, although overall appropriateness of the 2 370 contact-precaution days reached 80.0%, appropriateness fell to 48.6% for the 924 preventive isolation days applied before results were known [7], quantifying the over-isolation cost of a diagnostic lag; meanwhile missed front-line recognition and isolation of obvious C. difficile diarrhoea illustrates the opposite failure of under-triage. Together these findings converge on a single modifiable parameter-the interval from arrival to microbiological information-as the critical determinant of cross-infection control at the ED gateway.

3.4.2. Triage Accuracy, Zoning and Isolation Decision-Making

Accuracy is the hinge on which zoning decisions turn, but the infection-control return on accuracy depends on whether decision support is embedded in workflow rather than merely installed. A systematic review of nurse-triage implementation strategies grouped interventions into education (64%), technology (30%) and audit with feedback (6%), all yielding short-term gains in accuracy and knowledge, with workload and overcrowding as the dominant barriers and nurse experience, interprofessional collaboration and a continuous-improvement culture as facilitators [13]; Chinese platform-level data show triage concordance of 98.49% and target response-time attainment of 96.17% across 154 065 encounters after health-information-technology and big-data optimization [14]. This review highlights an "installed but unused" problem: the RETTS China knowledge base was applied in only 80% of encounters, with more than 87% of patients assigned to levels III–IV [15], indicating that decision support must be worked into routine flow. Feedback-driven whole-process management (22 689 vs 22 236 encounters one year apart) raised information completeness, level concordance and response-time compliance while shortening waiting and reducing waiting-related adverse events (P<0.05)[16]. Structural streaming complements scoring accuracy: a three-layer arrangement-outer checkpoint, respiratory/non-respiratory streaming at the entrance, routine full triage, with ambulance

rerouting and controlled personal protective equipment use-kept transmission risk low through the pandemic peak [4], and repurposing a psychiatric triage ward into a COVID-19 isolation unit shows how early cohorting contains institutional spread [5]. This review's appraisal: zoning works only when calibrated, since "screen-all with rapid release of negatives" outperforms purely precaution-based policies [6,7]; and because the supporting designs are quasi-experimental or historical-control, certainty for this domain remains low.

3.4.3. Intelligent and Remote Triage Technologies

Machine-learning models consistently outperform conventional scales in discrimination, but current evidence rests mainly on internal validation of retrospective data and does not yet support autonomous bedside use. A model developed on 163 452 ED visits achieved an AUROC of 0.917 versus 0.882 for the Canadian Triage and Acuity Scale and an area under the precision-recall curve of 0.629 versus 0.333, with mode of arrival, age and free-text chief complaints the leading predictors [20]; structured and scoping reviews support AI-based triage for identifying adults and children needing critical care, procedures or admission, with better discrimination and resource allocation than conventional triage [11,12]; and a rule-based telemedicine framework integrating 76 229 clinical rules with Internet of Medical Things sensing reached an expert-validated triage accuracy of 99.1% on a 750-patient dataset [21], while Chinese platform studies demonstrate the operational maturity of information-technology redesign and integrated triage-registration workflow reengineering [14,17]. This review stresses that the infection-control pathway here is indirect and conditional: finer, earlier stratification translates into earlier cohorting and less co-location of potentially infectious with non-infectious patients, but most models are internally validated and insufficiently transparent, and should augment rather than replace clinical judgement [11,12].

3.4.4. Crowding Relief and Patient Flow Restructuring

Crowding is simultaneously a cause and a consequence of ineffective triage and constrains every downstream IPC measure. The systematic review of ED crowding places inpatient boarding and bed shortages at the centre of the causal chain and documents delays and adverse outcomes as its effects [2]. The CRE study provides the sharpest quantitative warning: an ED stay longer than two days raised the adjusted odds of acquisition 4.58-fold, implying that structural throughput failure can overwhelm even well-executed screening [6]. A scoping review mapping 77 reviews, 202 performance indicators and 38 improvement interventions found that most interventions change practice and process, yet few report outcomes across time, proportion, process, cost and clinical domains simultaneously [22]. This review concludes that triage optimization must be bundled with bed-capacity governance, boarding limits and ambulance-destination control if its infection-control dividend is to persist [3-5].

3.4.5. Whole-Process Data Feedback and Continuous Improvement

Audit-and-feedback is the least used yet measurably effective strategy in the implementation literature [13];and whole-process, big-data-driven triage management converts routine records into corrective action by improving information completeness, level concordance and response-time compliance while reducing waiting and waiting-related adverse events [16]. This review judges that feedback loops are low-cost, workflow-neutral and demonstrably effective, but that the evidence for them is short-horizon and single-centre (low certainty) and their sustainability depends on visualisation and continuous operational ownership.

3.5. Evidence Extraction and Grading

Across outcome domains, certainty is moderate only for time to pathogen result and antimicrobial stewardship-both supported by large single-centre contrasts with consistent effect direction-and low for MDRO acquisition, triage discrimination and waiting-time outcomes, reflecting quasi-experimental designs, single-study support and heterogeneous metrics; it is very low for isolation appropriateness and for crowding and flow outcomes,

which rest on older or narratively synthesized evidence (Table 6). Notably, no included study reported staff occupational exposure with quantitative precision, an evident blind spot of the current literature. This review therefore treats the certainty map, rather than any single effect estimate, as its principal output.

3.6. This Review's Overall Judgement of the Evidence Body

Three cross-cutting judgements follow from the synthesis. First, triage optimization behaves as a bundled intervention, not a discrete tool: the included studies show that a rapid test without zoning, or a scoring model without flow management, interrupts only one link of the transmission chain, whereas combined education, technology and audit strategies outperform isolated measures [6,7,13]. Second, the certainty of the evidence is inversely related to its clinical importance-the outcomes that matter most for patients (organism acquisition, isolation appropriateness, flow) are precisely those with low or very low certainty-so the field's most consequential claims remain provisional. Third, the causal architecture is coherent but under-verified: each of the five mediating routes proposed in Figure 3 is supported by at least one quantified study, which establishes plausibility and dose–response coherence rather than proof. On this basis, the highest-value next step is not another single-centre before–after evaluation but standardised, multicentre prospective designs with pre-specified cross-infection endpoints.

4. Discussion

4.1. Interpretation of the Principal Findings

This review yields three convergent findings. First, front-door rapid diagnostics compress the detection-to-decision loop (3.1 vs 22.2 h) and this compression is directly monetized in infection-control currency-fewer antibiotics at admission, fewer room reallocations, fewer acquisition events and nearly halved antimicrobial consumption [6,19]. Second, accuracy is the hinge: machine-learning models [20,21], standardized knowledge bases and feedback-driven whole-process management all raise discrimination and concordance, and accuracy propagates downstream into correct zoning and fewer mis-located infectious patients. Third, structural throughput constraints can neutralize triage gains; when boarding exceeds two days the acquisition risk rises almost five-fold regardless of screening quality [2,6]. The practical implication is that triage optimization behaves as a bundled intervention rather than a discrete tool, an interpretation consistent with implementation research in which combined education, technology and audit strategies outperform isolated measures [13].

4.2. Transmission Pathways and Mediating Mechanisms

The mechanism-pathway framework organizes these findings into five mediating routes through which triage process optimization curbs cross-infection: earlier pre-emptive detection of suspected sources; shorter latency between arrival, result and decision; improved discrimination of acuity and transmissibility; reduced exposure duration for contact-risk patients; and alleviated crowding and clustering. A feedback loop-audit and big-data visualization-closes the system, converting routine triage records into corrective action [13,16]. Each route is documented by at least one quantified study in the evidence base, which supports the plausibility, coherence and dose–response plausibility of the causal chain linking entry-process redesign to transmission outcomes. The framework also explains why partial implementations disappoint: a rapid test without zoning, or a scoring model without flow management, interrupts only one link of the chain.

4.3. Implementation Considerations

Implementation evidence identifies workload and overcrowding as the dominant barriers, with nurse experience, interprofessional collaboration and a continuous-improvement culture as the strongest facilitators [13]. Three operational lessons follow. Knowledge bases must be workflow-embedded, because installed-but-unused decision support leaves discrimination gains unrealized [15]. Feedback must be continuous and

visual, since audit-and-feedback remains the least used yet measurably effective strategy and big-data feedback loops have already improved completeness, concordance and response times [16]. Finally, investment asymmetry matters: with only 15.2% of facilities meeting all IPC minimum requirements and high-income countries eight times more likely to hold advanced IPC implementation status, low- and middle-income settings-where 15 of every 100 patients acquire an infection-need low-cost configurations of the bundle, for which rule-based tele-triage frameworks and standardized national triage protocols offer realistic entry points.

To translate this into practice, this review proposes a three-tier implementation sequence. The mandatory front-door tier couples layered screening, rapid pathogen detection and empiric contact precautions with rapid release of negative patients. The decision tier embeds standardized or intelligent triage in workflow and links it to zoning and pre-emptive isolation. The system tier adds whole-process data feedback, bed-capacity and boarding governance, and ambulance-destination control. Paradoxically, the pandemic demonstrated that radical flow reconfiguration is feasible under pressure; the policy challenge is to institutionalize those gains in normal times [3,4].

4.4. Limitations

Several limitations qualify the findings. Clinical and methodological heterogeneity precluded quantitative pooling, so all conclusions rest on structured narrative synthesis. Although bilingual searching across eight sources mitigated language and database bias, grey literature beyond WHO IRIS was not exhaustively mined, and small unpublished evaluations may be missing. Three foundational pre-2020 studies were retained for mechanistic grounding [2,7,8]; they carry older-practice context, and their certainty was graded accordingly. Most primary studies were single-centre and retrospective, several reviews lacked protocol registration, and the single conference abstract could not be quality-checked in full [8]. Staff-facing outcomes, notably occupational exposure, were reported descriptively rather than quantitatively, and GRADE certainty for half of the outcome domains was low or very low. These constraints counsel interpretive caution without invalidating the direction of the evidence.

5. Conclusion

Evidence synthesized from 22 studies indicates that emergency department triage process optimization operates as a transmission-interruption instrument at the hospital gateway. Rapid molecular screening at entry shortens pathogen detection from hours to hours-or-less, and in combination with pre-emptive contact precautions it is associated with sharply reduced multidrug-resistant organism acquisition and antimicrobial consumption; intelligent decision support raises discrimination beyond conventional scales; and whole-process data feedback sustains accuracy and response-time compliance in routine operation. The certainty of this evidence is moderate for detection speed and antimicrobial stewardship, and low to very low for organism-level transmission and flow outcomes. Cross-infection control at triage is therefore best pursued as a bundle-front-door screening, accurate stratification, pre-emptive zoning, crowding relief and continuous audit-embedded within adequately resourced infection prevention and control programmes. Future research should prioritize multicentre prospective evaluations with standardized cross-infection endpoints, external and prospective validation of intelligent triage models, quantified staff-exposure outcomes, and implementation studies in resource-constrained settings where the preventable burden of healthcare-associated infection remains largest.

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Appendix (Source Materials)

The following table serves as the source material for this study. Tables 1 to 5 contain information on methodology and included studies; Table 6 synthesizes evidence by intervention dimension and provides a grading system; Table 7 is a structured template for filling in the data for the before-and-after comparison in our hospital. In Table 6, "reported effect in the literature" are example values. Please replace them with the actual data from our hospital in the final version.

Table 6. Evidence Synthesis and Certainty Grading by Intervention Domain

Intervention domain	Refs.	Key outcomes and reported effects	Level	Certainty	Review judgement
Front-door screening and pre-emptive isolation	[19][6][8][7]	The return of etiological results was 3.1 h vs. 22.2 h (P < 0.001). The use of antibiotics on admission was 66.1 % vs 80.3 %. The yield of CRE was 1.0 % vs 4.6 %. Antibiotics intensity 804 → 394 DDD / 1 000 patients.	Level 3	Detection time / antimicrobial management : medium ; mDRO gain : low	The effect is large and the direction is consistent, but it is a single-center retrospective; recommended binding with 'negative rapid release'
Triage accuracy, zoning and isolation	[13][4][5][14][15][16]	The coincidence rate of triage was 98.49 %. The target reaction time compliance rate was 96.17 % ; the utilization rate of knowledge base is 80 % ; the appropriateness of preventive isolation day was 48.6 % to the overall 80.0 %.	Level 3-4	cataphyll	Accuracy benefits are clear, and the transformation depends on workflow embedding and calibration.
Intelligent and remote triage	[11][20][21][12][14][17]	AUROC 0.917 vs. 0.882 ; aUPRC 0.629 vs. 0.333 ; the accuracy of expert verification was 99.1 %.	Level 3-4	cataphyll	Discrimination is better than the conventional scale, but more internal validation, retrospective ; it should be enhanced rather than replaced.
Crowding relief and flow restructuring	[6][4][5][3][22][2]	AOR = 4.58 (95 % CI 1.44-14.58) was obtained for CRE in patients with emergency stay > 2 days.	Level 5	very low	Structural throughput failure can overwhelm the screening effect ; it must be tied to bed and detention management.
Whole-process feedback	[13][16]	The information integrity rate, level coincidence rate and response time coincidence rate were improved. Waiting time and adverse events decreased (P < 0.05).	Level 3	cataphyll	The least used but quantifiable effective ; sustainability relies on visualization and

						operational ownership

Note : The ' literature report effect ' in the table is an example value, which is used to indicate the magnitude and direction of the outcome of each dimension. The official draft should be replaced with the real data of our hospital. The JBI level is based on the 2014 JBI evidence pre-classification system (Level 1 is experimental research evidence, Level 5 is expert opinion) ; gRADE deterministic evidence was high from the beginning of randomized controlled trials, and observational evidence was downgraded due to bias risk, inconsistency, indirectness and imprecision. This review has not been quantitatively combined, and the deterministic rating is based on a comprehensive judgment of the composition of the item-by-item outcome.

Table 7. Template for Before–after Comparison at the Study Hospital (Illustrative/placeholder)

Domain	Key indicator	Before optimization (our hospital) to be filled in	After optimization (hospital) to be filled in	Change rate (to be calculated)	P value (to be filled)	Reference
Rapid entrance screening	Time of return of etiological results (h)	-	-	-	-	3.1 vs. 22.2 [1]
Rapid entrance screening	Utilization rate of antibiotics at admission (%)	-	-	-	-	66.1 vs. 80.3 [1]
Rapid entrance screening	Intensity of antibiotic use (DDD / 1 000 patients)	-	-	-	-	394 vs. 804 [7]
Partition and isolation	MDRO (CRE) acquisition rate (%)	-	-	-	-	1.0 vs 4.6 [7]
Partition and isolation	Overall appropriateness of isolation measures (%)	-	-	-	-	80.0 (preventive 48.6) [18]
intelligent triage	Triage coincidence rate (%)	-	-	-	-	98.49[14]
intelligent triage	Target reaction time compliance rate (%)	-	-	-	-	96.17[14]
whole process management	Waiting time (min)	-	-	-	-	Significantly decreased (P < 0.05) [21]
whole process management	Waiting-related adverse events (cases)	-	-	-	-	Significantly decreased (P < 0.05) [21]

Note: ' before / after optimization ' and ' P value ' column please fill in the real data of our hospital, ' change rate ' is calculated by the first two columns; 'Literature example reference ' only provides the magnitude and direction reference of the same index, not the data of our hospital ; it is recommended to keep the original data source for verification.

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