

**DEVELOPMENT OF INFECTIOUS DISEASE
EMERGENCY RESPONSE TRAINING MODULES
AND ITS EFFECTIVENESS ON THE
COMPETENCY INDEX FOR
HEALTHCARE-ASSOCIATED INFECTION
PREVENTION AND CONTROL
PRACTITIONERS IN GUIZHOU PROVINCE,
CHINA**

ZHANG MAOJIE

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by

ZHANG MAOJIE

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“Long live the great unity of the people of the world!”

“May this journey lead us starward!”

TABLE OF CONTENTS

ACKNOWLEDGMENT	ii
TABLE OF CONTENTS	iii
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF SYMBOLS	xiv
LIST OF ABBREVIATIONS	xv
LIST OF APPENDICES	xvi
ABSTRAK	xvii
ABSTRACT	xix
CHAPTER 1 INTRODUCTION	1
1.1 Definition of healthcare-associated infection	1
1.2 The challenges of HAI in recent years	3
1.3 The threat of infectious diseases to human beings	6
1.4 Overview of HAI Prevention and Control Practitioners	7
1.5 Overview of Training mode and competency index system of HAI-PCPs	8
1.6 Problem statements	10
1.7 Rationale of the study	12
1.8 Significance of the Research	13
1.9 Research questions	14
1.10 Objectives	14

1.10.1 General objectives	14
1.10.2 Specific objectives:	15
1.11 Research hypothesis	15
CHAPTER 2 LITERATURE REVIEW	17
2.1 History of HAIs	17
2.1.1 Pre-bacteriological Era: Early Recognition of Hospital Infections	17
2.1.2 Post-bacteriological Era: Emergence of Disinfection and Aseptic Techniques	19
2.1.3 Antibiotic Era and the Challenge of Antimicrobial Resistance	21
2.1.4 Post-pandemic Era: Re-emerging Challenges for HAI Management	23
2.2 Prevalence and threat of HAIs	25
2.2.1 Global burden of HAIs	25
2.2.2 Epidemiology of HAIs in China	26
2.2.3 Drivers of increasing HAIs: an epidemiologic triad perspective	28
2.3 Overview of HAI-PCPs competency studies	30
2.4 The epidemic situation of infectious diseases.	33
2.5 Evolution of Medical and Legal Responses to Infectious Disease Emergencies .	35
2.6 Requirements of laws and regulations on HAI management	37
2.7 Definition and Application of Competency	38
2.8 The Application of the Delphi Method in Developing a Competency Model	41
2.9 Definition of Training	42
2.10 Developing the training module	44
2.11 Research Gap and Justification for the Current Study	46

2.12 Summary of Literature Review	48
2.13 Conceptual Framework	49
CHAPTER 3 METHODOLOGY	53
3.1 Phase I	54
3.1.1 Research Design	54
3.1.2 Study location	55
3.1.3 Study duration	57
3.1.4 Study Population	58
3.1.5 Sampling Frame	58
3.1.6 Subject criteria	58
3.1.7 Sample size calculation	60
3.1.8 Sampling method	61
3.1.9 Data Collection Process	61
3.1.10 Statistical Analysis	62
3.1.11 Development and validation the competency index	64
3.1.11(a) Draft Item Development Process	61
3.1.11(b) Delphi expert consultation	64
3.1.11(c) Pre-testing on the HAI-PCPs Competency Index	
Questionnaire	65
3.1.11(d) Pilot study on the HAI-PCPs Competency Index	
Questionnaire	65
3.1.11(e) Exploratory factor analysis on the HAI-PCPs	

Competency Index Questionnaire	66
3.2 Phase II	70
3.2.1 Research Design	70
3.2.2 Study location	70
3.2.3 Study duration	71
3.2.4 Study Population	71
3.2.5 Sampling Frame	72
3.2.6 Subject criteria	72
3.2.7 Sample size calculation	73
3.2.8 Sampling method	74
3.2.9 Data Collection Process	74
3.2.10 Statistical Analysis	75
3.2.11 Survey on HAI-PCPs' Competency	77
3.2.12 Factors Associated with Competency Scores among HAI -PCPs	78
3.3 Phase III	78
3.3.1 Research Design	78
3.3.2 Research location	79
3.3.3 Research duration	79
3.3.4 Study Population	79
3.3.5 Sampling Frame	80
3.3.6 Subject criteria	80
3.3.7 Sample size calculation	81

3.3.8 Sampling method	82
3.3.9 Data Collection Process	82
3.3.10 Statistical Analysis	82
3.3.11 Development and validation the training modules	83
3.4 Phase IV	87
3.4.1 Research Design	87
3.4.2 Research location	88
3.4.3 Research duration	88
3.4.4 Study Population	88
3.4.5 Sampling Frame	89
3.4.6 Subject Criteria	89
3.4.7 Sample Size Calculation	90
3.4.8 Sampling method	91
3.4.9 Data Collection Process	92
3.4.10 Statistical Analysis	93
3.4.11 Evaluation Timing for Training Effectiveness	94
3.4.12 Baseline and Reliability Assessment	95
3.4.13 Instructor Recruitment and Training	96
3.4.14 Verification the effectiveness of the training module	97
3.4.15 Identification factors associated with post-training competency	98
3.5 Ethical considerations	100
3.6 Summary of Quantitative and Qualitative Analysis	102

3.7 Summary flowchart of study	104
CHAPTER 4 RESULT	107
4.1 Phase I: Development and validation the competency index	107
4.1.1 Systematic review of HAI-PCPs Competency items	107
4.1.2 General information of experts included in expert consultation	112
4.1.3 HAI-PCPs Competency Index Questionnaire Expert Consultation First Round Feedback	114
4.1.4 HAI-PCPs Competency Index Questionnaire Expert Consultation Second Round Feedback	122
4.1.5 Pre-testing for HAI-PCPs Competency Index Questionnaire	124
4.1.6 Pilot study for HAI-PCPs Competency Index Questionnaire	125
4.1.7 Validation the items construct and determine the reliability of the HAI-PCPs competency index	127
4.2 Phase II: Factors Associated with Competency Scores among HAI Prevention and Control Practitioners	132
4.2.1 Competency Evaluation in Infectious Disease Emergency Response among HAI-PCPs in Guizhou Province	132
4.2.2 Factors Associated with Emergency Response Competency among HAI-PCPs in Guizhou Province, China	133
4.2.3 Training Needs Assessment for HAI-PCPs	143
4.3 Phase III: Development and validation the training modules	146
4.3.1 Development HAI-PCPs training module based on competency evaluation	146
4.3.2 General information of experts included in expert consultation	148
4.3.3 HAI-PCPs Training Module Questionnaire Expert Consultation First Round Feedback	150

4.3.4 HAI-PCPs Training Module Questionnaire Expert Consultation Second Round Feedback	152
4.3.5 Pre-testing for HAI-PCPs training module	154
4.4 Phase IV: Assessing the Effectiveness of the Training Module	155
4.4.1 General information of teaching experts	155
4.4.2 General information on training participants	158
4.4.3 Assessment of the Representativeness of Baselin Data	159
4.4.4 Pre-training reliability verification	159
4.4.5 HAI-PCPs competency-based training module effectiveness evaluation	160
4.4.6 Relevant factors for the competent of trainees after training	162
4.4.7 Satisfaction survey after training	164
CHAPTER 5 DISCUSSION	165
5.1 Phase I: Development and Validation of the Competency Index	165
5.2 Phase II: Assessment of Competency Status and Influencing Factors	167
5.3 Phase III: Development and Validation of the Training Module	170
5.4 Phase IV: Evaluation of Training Effectiveness and Influencing Factors	173
5.5 The theoretical and practical implications of the research results	177
5.5.1 Research Implications to Theory	177
5.5.2 Practical Implications for Training and Workforce Development	178
5.6 Strengths and Limitations	180
CHAPTER 6 CONCLUSION	184
6.1 Conclusion	184

6.2 Recommendations	185
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REFERENCES	188
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APPENDICES

LIST OF TABLES

	Page
Table 4.1 : Most-cited competencies	110
Table 4.2 : Characteristics of the Delphi experts	113
Table 4.3 : Expert judgment based on quantitative	114
Table 4.4 : Expert personal authority coefficient	114
Table 4.5 : HAI-PCPs Competency Index Expert Consultation Questionnaire	115
Table 4.6 : Content validity index of level I&II items of HAI-PCPs Competency items	116
Table 4.7 : HAI-PCPs Competency Index Expert Consultation Questionnaire level III Items List	117
Table 4.8 : Content validity index of level III items of HAI-PCPs Competency items(first round)	121
Table 4.9 : Content validity index of level III items of HAI-PCPs Competency items(second round)	123
Table 4.10 : Face validity index of HAI-PCPs Competency index items	124
Table 4.11 : Characteristics of the HAI professionals in studies	126
Table 4.12 : Results of the exploratory factor analysis	130
Table 4.13 : General characteristics and competency scores of HAI-PCPs (n = 209)	134
Table 4.14 : General characteristics and competency scores of HAI-PCPs (n = 209) (merged)	136
Table 4.15 : Results of Simple Logistic Regression Analysis for Factors Associated with Competency Status among HAI-PCPs	137
Table 4.16 : Results of Stepwise Multiple Logistic Regression Analysis for	

Factors Associated with Competency Status	141
Table 4.17 : Results of Multiple Logistic Regression Analysis Including Interaction Terms	142
Table 4.18 : HAI-PCPs competency evaluation low-scoring items	144
Table 4.19 : Summary Table of HAI-PCPs Training Mode and Training	145
Table 4.20 : Characteristics of the Delphi experts	148
Table 4.21 : Expert judgment based on quantitative	150
Table 4.22 : Expert personal authority coefficient	150
Table 4.23 : Content validity index of HAI-PCPs training module (first round)	151
Table 4.24 : Content validity index of HAI-PCPs training module (second round)	153
Table 4.25 : HAI-PCPs training module teaching method expert selection	154
Table 4.26 : Face validity index of HAI-PCPs training framework	155
Table 4.27 : Characteristics of the Trainers	156
Table 4.28 : Feedback Form for Trainers before training	157
Table 4.29 : Characteristics of the HAI-PCPs in training	158
Table 4.30 : Baseline data analysis results of pre-training	159
Table 4.31 : Competency rating chart for before training, after training, and a one-month gap after training	160
Table 4.32 : Pairwise Comparison results with T0, T1 and T2	161
Table 4.33 : The results of the McNemar test for T0 and T1	161
Table 4.34 : General Characteristics of Trainees Who not competent before Training	164

LIST OF FIGURES

	Page
Figure 1.1 : Basic classification of healthcare-associated infections.....	2
Figure 2.1 The epidemiological triad demonstrates the three factors that interact to cause illness.	29
Figure 2.2 : ADDIE instructional design framework.....	46
Figure 2.3 : Conceptual Framework of Competency Oriented Training.....	52
Figure 3.1 : Map of Guizhou province.....	57
Figure 3.2 : Flow chart of Phase I.....	70
Figure 3.3 : Flow chart of Phase II-III.....	85
Figure 3.4 : Flow chart of Phase IV.....	100
Figure 3.5 : The summary flowchart of this study.....	104
Figure 3.6 : Flowchart of this study.....	105
Figure 4.1 : PRISMA flow diagram of screening process for the systematic review of the literature.....	109
Figure 4.2 : Intersection graph of competency domain (generated by this study) .	111
Figure 4.3 : Distribution chart of HAI PCPs competency self-assessment results..	133
Figure 4.4 : ROC Curve of the HAI-PCPs Competency Classification Model.....	143
Figure 4.5 : Competency score box plot for T0,T1 and T2.	160
Figure 4.6 : Competence before and after T0 and T1 training.....	162

LIST OF SYMBOLS

n	Sample size
p	p -value (probability value)
M	Mean (average)
SD	Standard Deviation
α	Significance level (commonly set at 0.05)
OR	Odds Ratio
CI	Confidence Interval (usually 95%)
χ^2	Chi-square statistic
df	Degrees of freedom
$>$	greater than
$<$	less than
$\geq$	greater than or equal to
$\leq$	less than or equal to
$=$	equal to
%	percentage

LIST OF ABBREVIATIONS

HAI	Healthcare-associated infection
HI	Hospital infection
NI	Nosocomial infection
IPC	Infection Prevention and Control
HAI-PCP	Healthcare-associated infection Prevention and Control Practitioner
MDR	Multi-drug-resistant
COVID-19	Coronavirus Disease 2019
WHO	World Health Organization
APIC	Association for Professionals in Infection Control and Epidemiology
ICNA	Infection Control Nurses Association
ADDIE	Analysis, Design, Development, Implementation, and Evaluation
USM	Universiti Sains Malaysia
SD	Standard Deviation

LIST OF APPENDICES

Appendix A : Competencies for HAI-PCPs

Appendix B : Ethical approval A-1

Appendix C : Ethical approval A-2

Appendix D : Ethical approval B-1

Appendix E : Management Measures for Hospital Infection(China)

Appendix F : Subject Information and Consent Form

Appendix G : Subject Information and Consent Form

Appendix H: Characteristics and professional diversity of Delphi experts

Appendix I : Delphi HAI-PCPs Competency Consultation Questionnaire

Appendix J : Formal HAI-PCPs Competency index Questionnaire

Appendix K : Delphi HAI-PCPs training module Consultation Questionnaire

Appendix L : Training module framework

Appendix M : Training Recruitment Notice

Appendix N : Expert Review Form for Training Module Evaluation

Appendix O : Training process photos

**PEMBANGUNAN MODUL LATIHAN TINDAK BALAS
KECEMASAN PENYAKIT BERJANGKIT DAN
KEBERKESANANNYA TERHADAP INDEKS KOMPETENSI
PENGAMAL PENCEGAHAN DAN KAWALAN JANGKITAN
BERKAITAN PENJAGAAN KESIHATAN DI WILAYAH
GUIZHOU, CHINA**

ABSTRAK

Jangkitan berkaitan penjagaan kesihatan (HAIs) merupakan cabaran utama kepada sistem kesihatan global. Kompetensi Pengamal Pencegahan dan Kawalan Jangkitan (PCPs) adalah penting untuk keberkesanan pencegahan HAI. Penilaian kompetensi bukan sahaja mencerminkan keupayaan pengamal, tetapi juga membimbing reka bentuk latihan yang disasarkan. Namun, tiada modul latihan berasaskan kompetensi telah dibangunkan untuk PCP di Wilayah Guizhou. Kajian ini bertujuan membangunkan dan mengesahkan modul latihan tindak balas kecemasan penyakit berjangkit berasaskan kompetensi untuk PCP, serta menilai keberkesanannya dalam meningkatkan tahap kompetensi pengamal. Kajian ini dijalankan dalam empat fasa. Fasa I melibatkan pembangunan dan pengesahan indeks kompetensi melalui kajian literatur dan kaedah Delphi. Fasa II menilai tahap kompetensi PCP dan mengenal pasti faktor yang mempengaruhi serta keperluan latihan. Dalam Fasa III, modul latihan dibangunkan dan disahkan berdasarkan jurang yang dikenal pasti. Fasa IV menilai keberkesanan latihan melalui penilaian sebelum,

selepas, dan satu bulan selepas latihan. Selepas dua pusingan konsultasi Delphi melibatkan lapan pakar, satu indeks kompetensi akhir dengan 44 item merentasi lima dimensi telah dibangunkan. Penilaian awal secara keratan rentas dalam kalangan 209 PCP mendapati hanya 36.8% mencapai tahap kompetensi. Analisis univariat menunjukkan umur, pengalaman kerja, dan tahap pendapatan mempengaruhi skor kompetensi dengan ketara ($p < 0.05$), manakala analisis multivariat menunjukkan kesahihan ramalan yang boleh diterima ($AUC = 0.735$). Berdasarkan jurang dan keperluan latihan, 13 modul latihan khusus telah dibangunkan dan dilaksanakan. Selepas menyertai program latihan, 60 PCP menunjukkan peningkatan ketara dalam skor kompetensi mereka ($p < 0.01$), yang kekal tinggi selepas satu bulan ($p < 0.01$). Peserta melaporkan bahawa kandungan latihan adalah praktikal, relevan, dan selaras dengan keperluan profesional mereka. Modul latihan berasaskan kecekapan telah berjaya meningkatkan keupayaan respon kecemasan dalam kalangan pengamal Pencegahan dan Kawalan Jangkitan Berkaitan Penjagaan Kesihatan (HAI-PCPs) di Wilayah Guizhou. Satu soal selidik penilaian kecekapan yang sah telah dibangunkan bagi mengenal pasti keperluan latihan dan menilai keberkesanan hasil latihan. Kajian ini menekankan kepentingan kerangka kecekapan dalam membimbing reka bentuk latihan dan menyediakan rujukan praktikal untuk memperkukuh kawalan jangkitan dalam persekitaran yang serupa.

Kata kunci: Kompetensi, Jangkitan Berkaitan Penjagaan Kesihatan, Respon Kecemasan, Modul Latihan, Pengamal Pencegahan dan Kawalan Jangkitan

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CONTROL PRACTITIONERS IN GUIZHOU PROVINCE,
CHINA**

ABSTRACT

Healthcare-associated infections (HAIs) pose a major challenge to global health systems. The competence of Infection Prevention and Control Practitioners (PCPs) is essential for effective HAI prevention. Competency assessment not only reflected practitioners' capabilities but also informed the design of targeted training. However, no competency-based training module had been established for HAI-PCPs in Guizhou Province. This study aimed to develop and validate a competency-based infectious disease emergency response training module for HAI-PCPs and to evaluate its effectiveness in improving practitioner competence. The study was conducted in four phases. In Phase I, a competency index was developed and validated through literature review and Delphi consultation. In Phase II, the competence of HAI-PCPs was assessed, and key influencing factors and training needs were identified. In Phase III, training modules were designed and validated based on the identified gaps. In Phase IV, training effectiveness was evaluated

through pre-, post-, and one-month follow-up assessments. Following two rounds of Delphi consultation with eight experts, a final competency index comprising 44 items across five dimensions was developed. A cross-sectional baseline assessment among 209 HAI-PCPs revealed that only 36.8% met the competency threshold. Univariate analysis showed that age, work experience, and income level significantly associated with competency scores ($p < 0.05$), and multivariate analysis demonstrated acceptable predictive validity ($AUC = 0.735$). Based on the identified gaps and training needs, 13 targeted training modules were developed and implemented. After participating in the training program, 60 HAI-PCPs showed significant improvement in their competency scores ($p < 0.01$), which remained elevated at one-month follow-up ($p < 0.01$). Participants reported that the training content was practical, relevant, and well-aligned with their professional needs. The competency-based training module effectively improved the emergency response capabilities of HAI-PCPs in Guizhou Province. A validated competency evaluation questionnaire was developed to identify training needs and measure outcomes. The study underscored the value of competency frameworks in guiding training design and provided a practical reference for strengthening infection control in similar settings.

Keywords: Competence, Healthcare-Associated Infection, Emergency Response, Training Modules, Infection Prevention and Control Practitioners

CHAPTER 1

INTRODUCTION

1.1 Definition of healthcare-associated infection

Healthcare-associated infection (HAI), also referred to as hospital infection (HI) or nosocomial infection (NI), encompasses any infection acquired by patients during medical care (Khan et al., 2015). Such infections generally appear 48 hours or more after admission, and the patient shows no signs of infection or is not in the incubation period at the time of admission (Sikora and Zahra, 2023). HAIs can arise during the hospital stay or even after discharge, with pathogens including bacteria, viruses, fungi, and other microorganisms (Khan et al., 2017). Since HAIs originate within healthcare settings, patients undergoing medical treatment and healthcare staff may become potential hosts, extending the range of those threatened by HAI (Alamer et al., 2022). The most critical categories of HAIs are associated with invasive devices, such as central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), ventilator-associated pneumonia (VAP), and surgical site infections (SSI) (Arzilli et al., 2024). Many device-related infections and SSIs are due to multi-drug-resistant organisms (MDROs), such as *Clostridium difficile*, *methicillin-resistant Staphylococcus aureus* (MRSA), *vancomycin-resistant Enterococci* (VRE), and multi-resistant Gram-negative bacilli (Dadi et al., 2021). Healthcare workers are also at risk, facing cross-infections and occupational exposure incidents like needle-stick injuries (Mengistu et al., 2021). Figure 1.1 shows

the basic classification of HAI.

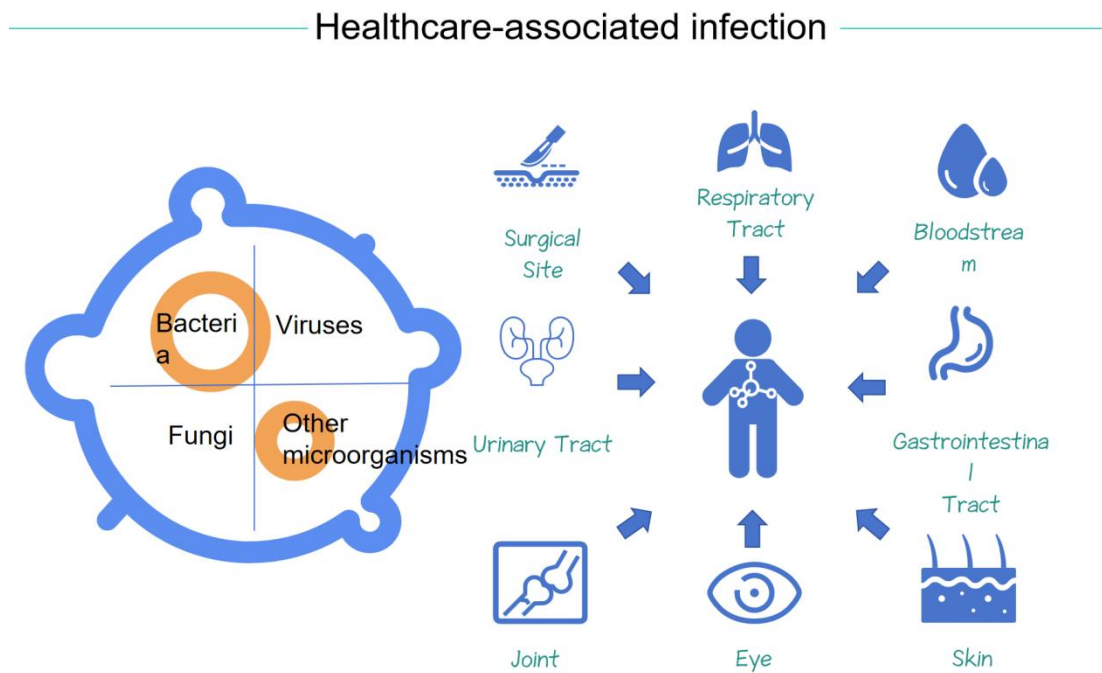


Figure 1.1: Basic classification of healthcare-associated infections.

As infectious diseases, HAIs spread through various routes: direct contact, indirect contact, droplet transmission, airborne transmission, and vector-borne transmission (Tozzo et al., 2022) . The global COVID-19 pandemic has enhanced awareness of infectious disease transmission and preventative measures among healthcare workers and the general population. Correspondingly, HAI prevention strategies focus on environmental cleaning and disinfection, indoor air quality, isolation, and hand hygiene(Peters et al., 2022).

HAIs impose a substantial burden on healthcare systems, leading to increased morbidity, mortality, and healthcare costs. According to the World Health Organization (WHO)'s Global Report on Infection Prevention and Control 2024, HAIs remain among the most frequent adverse events in healthcare delivery, affecting approximately one in every ten patients in acute-care settings, with an even

higher frequency observed in low- and middle-income countries and high-risk units such as intensive care units(WHO, 2024). The incidence in low- and middle-income regions is likely even higher due to limited surveillance data(Coker et al., 2022)HAIs remain one of the primary complications of modern medical care(Gidey et al., 2023). In the United States, HAIs are the sixth leading cause of death, exceeding the combined deaths from HIV, cancer, and traffic accidents(Liu and Dickter, 2020).

As the WHO emphasized, no country or healthcare system is immune to HAIs(Tomczyk et al., 2022). HAIs present a global population health issue. For over a century, healthcare professionals have focused on HAI control, and countries worldwide have implemented various HAI management practices to minimize the economic losses and health consequences associated with these infections (Sandu et al., 2025).

1.2 The challenges of HAI in recent years

The continuous development of monitoring and prevention practices for HAIs has been a consistent focus of infection control experts worldwide. However, evidence from China indicates that HAI management remains challenged by gaps in management systems, limited standardization of personnel evaluation, and inconsistent supervision mechanisms (J. Wang et al., 2018) . Additionally, new challenges have emerged. Chinese experts highlight three significant challenges facing full-time HAI control personnel in the country: new infectious diseases, multi-drug-resistant (MDR) bacteria, and classic infectious diseases (Xiujuan and

Anhua, 2019) . Infectious diseases present a persistent challenge for humanity, and during epidemics, hospitals serve as critical locations for patient treatment and isolation. Consequently, HAI control has become a central component of epidemic prevention and control, although substantial challenges persist.

In recent years, HAIs have attracted increasing global attention, prompting continuous efforts by infection prevention and control (IPC) specialists to improve monitoring and preventive measures. The growing importance of infection prevention and antimicrobial resistance (AMR) is now recognized as crucial for delivering high-quality, safe healthcare. It forms an essential component of public health emergency preparedness and response (Dhingra et al., 2020) . In 2022, the World Health Organization (WHO) released its first global report on IPC, providing a comprehensive analysis of the worldwide implementation of IPC programs. The report underscores the harmful effects of HAIs and AMR on patients and healthcare workers alike (Balakrishnan, 2022; World Health Organization, 2022). As one of the most populous countries, China's healthcare system faces considerable pressures and challenges: emerging infectious diseases, MDR bacteria, and classic infectious diseases (Yang et al., 2023).

Emerging infectious diseases impose heightened demands on HAI control personnel. Accelerating globalization and climate change have led to the frequent emergence of new infectious diseases, such as SARS, avian influenza, and COVID-19 (McNeely, 2021) . These diseases often exhibit rapid transmission and high infectivity, substantially damaging healthcare systems. Consequently, HAI

control personnel must remain vigilant in tracking epidemic trends, reinforcing preventive measures, and enhancing healthcare workers' awareness of infection control, ensuring hospitals serve as strongholds for epidemic prevention.

MDR bacteria represent a severe, escalating challenge. The widespread use of antibiotics has led to an increase in MDR bacteria, including strains like methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococci* (VRE). These bacteria exhibit resistance to multiple antibiotics, complicating treatment efforts (Tarín-Pelló et al., 2022). To combat MDR infections, HAI control personnel must strengthen collaboration with clinicians, promote the judicious use of antibiotics, and work to reduce the development and spread of resistant bacteria.

Classic infectious diseases remain a major area of focus for HAI control personnel. Traditional infectious diseases such as influenza, pneumonia, and dysentery have well-established control measures; however, their potential for outbreak and transmission persists (Haopeng Li et al., 2022). Preventing these infections is crucial in densely populated areas with limited healthcare resources. Effective management of classic infectious diseases remains essential in ensuring the health and safety of these populations.

Confronted with these challenges, HAI Prevention and Control Practitioners in China, must continually enhance their professional skills and response capacities. Moreover, government and social stakeholders should intensify investment and support to improve the personnel evaluation and supervision systems, thereby

strengthening the healthcare system's overall infection control capacity. These measures are essential to addressing the challenges posed by HAIs and ensuring the health and safety of the population.

1.3 The threat of infectious diseases to human beings

Infectious diseases are one of the challenges that human beings continue to face. Infectious diseases like COVID-19, tuberculosis, malaria, and HIV continue to cause millions of deaths annually. The emergence of new pathogens and the re-emergence of controlled diseases are significant concerns (Tobin, 2022). Infectious disease emergencies are often challenging to control effects in a short period. They are causing severe harm to the economy, society, culture, and other fields. In their reports on analyzing the experience and lessons learned from the rescue of infectious disease emergencies, scholars in the field of health pointed out that the lack of experienced medical personnel is the main obstacle to disease prevention and control (Cohen et al., 2022; Keil et al., 2024).

During the global trend of COVID-19, the incidence of HAI increased significantly, exposing the shortcomings and weaknesses of HAI management (Nabe-Nielsen et al., 2021). At the same time, during the COVID-19 epidemic, Chinese HAI-PCPs undertook a range of additional responsibilities beyond routine infection management. These included the planning and reconfiguration of existing healthcare and non-healthcare facilities to meet the operational requirements of general outpatient services, fever clinics, shelter hospitals, and centralized isolation

facilities such as designated hotels. Experiences from the COVID-19 response highlight the expanding scope of HAI practice and underscore the growing need for HAI management personnel to be prepared to address both established and emerging infectious disease threats in the future.

1.4 Overview of HAI Prevention and Control Practitioners

One of the most effective strategies for improving HAI control is cultivating and establishing dedicated management teams. As the core HAI prevention and control workforce, HAI-PCPs are central to implementing and sustaining HAI prevention efforts within hospitals. In the United States, these professionals are known as Infection Preventionists (IPs) (Gilmartin et al., 2021), while in Australia, they are called Infection Control Professionals (ICPs) (Mitchell et al., 2015). The World Health Organization (WHO) also provides a clear definition of practitioners in this field, emphasizing that preventing harm to patients, health workers (HWs), and visitors due to HAIs is essential for delivering safe, quality care, reducing antimicrobial resistance (AMR), and minimizing the transmission of infectious diseases.

China's health reform that began in the late 1990s has focused on strengthening health system performance, including the development of health management capacity and workforce (Tao et al., 2020). In alignment with this goal, China has established HAI management departments, designated responsibility to relevant units, and assigned full-time HAI personnel to oversee HAI prevention and control

management. These professionals are specifically responsible for monitoring, guiding, supervising, and providing training in HAI management across healthcare facilities. But hospitals lack expertise and human resources skilled in infection management. Senior managers fail to consider qualified personnel. A few health care institutions simply fill available vacancies with retired nurses to ensure the number of required personnel in the department of HAI.(Sun, 2016)

It is important to clarify that HAI-PCPs differ from hospital administrators. While HAI managers focus primarily on healthcare-related processes, such as managing HAI cases and addressing multidrug-resistant organisms, administrators are generally concerned with operational aspects of hospital management, including cost control and staffing. Thus, HAI management and hospital administration represent distinct roles with unique responsibilities.

1.5 Overview of Training mode and competency index system of HAI-PCPs

HAI-PCPs are vital in preventing and controlling HAIs. HAI management is rapidly developing in system construction, discipline construction, and capacity building (Jin et al., 2025) . Recently, the WHO released the core framework of the competency model for infection prevention and control personnel, which is an attempt by the WHO to integrate existing global resources. This document is intended to guide countries and medical institutions in cultivating the required IPC personnel. At the same time, for the professional level of such personnel, it is necessary to develop criteria for core competence qualification, in combination with

competency stratification, to better evaluate the comprehensive capabilities of professionals (Silva et al., 2023).

In recent years, some researchers in China have been focusing on the research on the training and evaluation system of full-time infection control personnel. However, there are few studies on the evaluation criteria for the core competence of full-time infection Prevention and Control Practitioners in China (Tu et al., 2025). Medical colleges and universities lack unique training and assessment plans for HAI management ability (Zong et al., 2020). The coverage of continuing education for full-time infection Prevention and Control Practitioners in hospitals of all provinces and cities is low, and the level of training needs to be more satisfactory. Many pieces of training are doomed to be difficult to achieve good results before implementation because there is a lack of competency assessment for positions (WHO, 2024). There is a lack of specific core competence criteria for full-time personnel, and a specific core competence evaluation system for full-time infection Prevention and Control Practitioners has not been developed. Developing a competency model for HAI-PCPs, especially post-pandemic, is essential to ensure they can effectively handle public health emergencies. A validated competency evaluation model can help improve HAI-PCPs in hospitals (Cui et al., 2022).

Therefore, in future research, it is necessary to define the concept of core competence of full-time HAI-PCPs, construct the evaluation index of core competence applicable to full-time personnel, understand the current situation of post-competence of infection control personnel, explore the influencing factors of

post competence, and provide a valuable reference for HAI management, in combination with the personnel composition and work characteristics of HAI management in China. It also provides objective criteria for appointing, assessing, and evaluating full-time personnel. Understand the gap between the staff themselves and the job requirements, match the future development needs, and adapt to the challenges faced by HAI management.

1.6 Problem statements

HAIs remain one of the most persistent yet preventable threats to patient safety and global public health. Each year, HAIs affect millions of patients worldwide, contributing to prolonged hospital stays, increased antimicrobial resistance, avoidable morbidity, and mortality. In China, the burden of HAIs is further intensified by regional disparities in healthcare infrastructure and workforce capacity, particularly in under-resourced provinces such as Guizhou.

Despite ongoing national initiatives to strengthen infection prevention and control, substantial challenges persist at the implementation level. One of the most critical gaps lies in the absence of a standardized and empirically validated competency framework for HAI-PCPs. Existing training programs for HAI-PCPs are often fragmented, inconsistent, and insufficiently aligned with actual role demands, with limited mechanisms for systematic competency assessment or evaluation of training effectiveness.

These limitations become especially evident in high-risk and time-sensitive

situations. Experiences from recent infectious disease events, including the COVID-19 pandemic, have highlighted deficiencies in emergency preparedness, role clarity, and applied competency among infection control personnel. Inadequate capacity to respond effectively to rapidly evolving infection risks has compromised HAI management in both routine clinical settings and emergent situations, increasing the risk of institutional outbreaks and undermining healthcare system resilience.

In this study, “infectious disease emergency response” is operationally defined as an integrated set of advanced and integrative infection prevention and control competencies required by HAI-PCPs to manage high-risk, complex, and time-sensitive infection control scenarios within healthcare settings, rather than being limited to large-scale outbreaks or exceptional public health crises. Rather, it is defined as a set of advanced and integrative competencies required by HAI-PCPs to manage high-risk, complex, and time-sensitive infection control scenarios within healthcare settings. Such scenarios include emerging infectious disease outbreaks, clusters of HAIs, transmission of multidrug-resistant organisms, and sudden failures of routine infection prevention systems. Many routine HAI challenges share core characteristics of emergency contexts, including uncertainty, rapid transmission potential, constrained response time, and the need for coordinated decision-making.

Accordingly, emergency response competency is conceptualized in this study as a critical application context for integrating and assessing infection prevention and control competencies, rather than as a separate or episodic function. In Guizhou Province, the lack of a validated competency index and a structured,

competency-based training framework limits the ability to systematically evaluate practitioner preparedness and to design targeted capacity-building interventions. Addressing this gap is essential for improving the effectiveness, consistency, and sustainability of HAI-PCPs in resource-constrained healthcare settings.

1.7 Rationale of the study

To address the persistent challenges in infection prevention and control, it is essential to develop and validate a context-specific competency evaluation tool, alongside establishing a targeted training system tailored to the roles and responsibilities of HAI-PCPs in China. These efforts are vital not only to improve the effectiveness, resilience, and sustainability of HAI management at both institutional and national levels, but also to bridge the current gaps in practice and preparedness.

Establishing a scientifically grounded competency evaluation index is critical for aligning practitioners' capabilities with the demands of modern HAI control, especially in the context of emerging infectious disease threats. Competent professionals play a pivotal role in reducing the harm caused by HAIs to patients, families, and healthcare workers, thereby enhancing the overall quality of healthcare services. Strengthening HAI-PCPs' capacity to assess and respond to infectious disease emergencies can significantly boost their confidence and effectiveness in critical situations.

Professional competency is closely linked to structured career development. A validated competency index not only facilitates more effective training but also

serves as a reference for performance evaluation, promotion, and future appointment of HAI-PCPs. Therefore, this study seeks to develop and validate such an index and to construct a corresponding training model, providing a systematic foundation for improving professional competencies and advancing HAI prevention and control practices in China.

1.8 Significance of the Research

- a. Improved HAI Management in Resource-Limited Settings: By focusing on Guizhou Province—a region with economic and healthcare disparities—the study offers a replicable model for improving HAI management in similar low-resource settings within China and other low- and middle-income countries (LMICs).
- b. Evidence-Based and Needs-Driven Training Design: By linking baseline competency assessment results with training content, the study ensures that the developed modules are targeted, relevant, and effective. This enhances the practical competency of HAI-PCPs and contributes to sustainable capacity building.
- c. Contribution to Global IPC Practices: The validated competency framework and training modules add to the global body of knowledge on infection prevention. They align with WHO goals for strengthening IPC programs and can serve as a reference for international health policy development, especially in LMIC contexts.
- d. Policy Relevance and Scalability: The competency index and training modules

developed in this study can inform national policy for standardizing HAI-PCP training and evaluation. They offer tools that are both adaptable and scalable across regions in China and beyond.

1.9 Research questions

1. What are the core competency domains and items required for HAI-PCPs in Guizhou Province to effectively respond to infectious disease emergencies?
2. What is the current level of infectious disease emergency response competency among HAI-PCPs in Guizhou Province, and which demographic and professional factors are associated with competency status?
3. What training needs can be identified based on competency assessment results among HAI-PCPs in Guizhou Province?
4. Does participation in a competency-based infectious disease emergency response training module lead to measurable changes in competency scores and competency classification among HAI-PCPs?

1.10 Objectives

1.10.1 General objectives

To enhance the competency of HAI-PCPs in Guizhou Province, China, through the systematic development, validation, and evaluation of evidence-based training modules.

1.10.2 Specific objectives:

Phase I

1. To develop a competency index for infectious disease emergency response using systematic review and Delphi expert consultation.
2. To examine the content validity, construct validity, and reliability of the competency index.

Phase II

3. To assess baseline competency levels and to identify factors associated with competency.

Phase III

4. To develop competency-based training modules based on identified competency gaps, guided by the ADDIE instructional design model.

Phase IV

5. To evaluate the effectiveness of the training modules using repeated competency assessments.

1.11 Research hypothesis

1. There is a statistically significant association between demographic and professional characteristics and the competency level of HAI-PCPs in infectious disease emergency response.
2. Participation in recent professional training is significantly associated with a higher likelihood of being competent in infectious disease emergency response

among HAI-PCPs.

3. HAI-PCPs who participate in the competency-based infectious disease emergency response training module demonstrate a statistically significant improvement in competency scores after training compared with baseline.

4. The proportion of HAI-PCPs classified as competent significantly increases after completion of the competency-based training module.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews existing literature related to HAI prevention and control, with particular attention to the competency requirements and training models for HAI-PCPs. While international frameworks such as those developed by WHO, APIC, and ECDC are well-established, there remains a lack of localized standards and validated competency models in China, especially in under-resourced regions like Guizhou Province.

In the post-COVID-19 era, emerging infectious disease threats have highlighted critical gaps in emergency preparedness, workforce competency, and training strategies. Against this backdrop, this chapter aims to:

- a. Trace the evolution and current challenges of HAI prevention and control;
- b. Identify research gaps in existing competency frameworks and training models, particularly in the Chinese context;
- c. Establish the theoretical and methodological foundation for this study, including the Delphi method and the ADDIE instructional design model.

2.1 History of HAIs

2.1.1 Pre-bacteriological Era: Early Recognition of Hospital Infections

Since the establishment of hospitals, HAIs have existed as an inherent risk of medical care (Ewelina et al., 2021). However, the scientific understanding of HAIs

and the necessity of reducing their occurrence have gradually been recognized, deepened, and resolved by modern science in development. The history of HAIs can be summarized into three stages.

The first stage was before the bacteriological era, in the 19th century, when people believed that purulent infections after trauma were inevitable because they had not yet recognized the microorganisms in nature and could not take preventive measures (Qadan and Cheadle, 2009) . In 1841, Hungarian obstetrician Ignaz Semmelweis recorded that the mortality rate in the ward where medical students delivered babies was three times higher than that in the ward next to a midwife (Wyklicky and Skopec, 1983) . He hypothesized that this situation was caused by medical students frequently coming into contact with corpses, leading to the spread of infection. Later, through mandatory hand washing, the infection rate sharply decreased. For example, Holmes discovered puerperal fever in 1843 (Colebrook, 1956), a well-known and dangerous disease in Europe. The hospital was once called a 'place of death' because of it. In the mid-19th century, Austrian doctor Semmelweis conducted in-depth research on puerperal fever. He found that postpartum fever is closely related to the cleanliness of the mother and the hospital environment (Ataman et al., 2013) . Koch further proposed the concept of "aseptic surgery," emphasizing maintaining a sterile environment during delivery to prevent the occurrence of puerperal fever (Pennington, 1995) . For example, Florence Nightingale, one of the most famous nurses in the world, improved the environmental sanitation conditions of hospitals during the war, carried out planned

environmental cleaning, improved water safety, and adequately treated sewage and garbage (Fee et al., 2010). Secondly, a series of measures such as improving ward layout and managing patients by zoning and classification were implemented, resulting in a reduction in the mortality rate of British soldiers during the Crimean War from approximately 40% to around 2% (Fee et al., 2010). In the above examples, the shadow of strategies in modern hospital infection management can be found, such as standard prevention, environmental hygiene, aseptic concept, hand hygiene concept, etc. It can also be observed that the development of HAI management has been evolving through continuous practice and summarization.

2.1.2 Post-bacteriological Era: Emergence of Disinfection and Aseptic Techniques

The second stage is the post-bacteriology era. After the 19th century, people gradually became aware of microorganisms. British surgeon Lister first clarified the relationship between bacteria and infection and proposed the concept of disinfection (Newsom, 2003). Before the 19th century, surgery was a risky treatment method. Due to the lack of understanding of the relationship between bacteria and infection in the medical community at that time, the operation was often accompanied by an extremely high infection rate, and many patients died of infection after surgery. However, the emergence of Lister brought a turning point to this dilemma. Lister conducted an in-depth study of the relationship between bacteria and infection and first proposed the concept of disinfection. He realized that infections during surgery

were often caused by bacteria invading the wound. Therefore, the infection rate can be effectively reduced by eliminating bacteria in surgical instruments and surgical areas (Newsom, 2003). In order to verify this theory, Lister conducted a series of experiments. He used carbolic acid solution to disinfect surgical instruments and strictly cleaned the surgical area before surgery. Implementing these measures significantly reduced the infection rate after surgery, and many lives initially thought to be unsavable were continued. In addition to the theory of disinfection, Lister also made outstanding contributions in other fields. He proposed the concept of aseptic surgery, emphasizing the need to maintain an absolute sterile state in the surgical area during surgery. In addition, he also studied the wound healing process, laying the foundation for the later development of wound repair and plastic surgery (Newsom, 2003). French microbiologist Pasteur discovered microorganisms in the air under a microscope and used methods such as heating disinfection to reduce their number and thus control infection (Mostowy, 2022). After repeated experiments, he used methods such as heating disinfection to reduce the number of microorganisms, opening up a new way to control infection. This groundbreaking research not only brought good news to the medical community but also provided protection for people's daily lives. As Pasteur's research gradually deepened, aseptic technology came into being. Aseptic technology refers to a series of measures under specific conditions to prevent microorganisms from entering the experimental or operating environment, thereby ensuring the accuracy and safety of the experiment or operation (Mostowy, 2022). The emergence of aseptic technology has greatly

improved the medical level and the success rate of surgery and saved the lives of countless patients. Subsequently, the era of steam sterilization came. Steam sterilizers use high-temperature and high-pressure steam to kill microorganisms, with the advantages of high efficiency, speed, and safety, and quickly became the most popular disinfection tool at the time (Miguel et al., 2024). The widespread use of steam sterilizers has further promoted the development of aseptic technology and provided strong support for the progress of medical care.

2.1.3 Antibiotic Era and the Challenge of Antimicrobial Resistance

The third stage is the antibiotic era. In 1928, British scientist Alexander Fleming accidentally discovered penicillin in an experiment, which laid the foundation for the subsequent antibiotic era (Bennett and Chung, 2001). Penicillin has a strong antibacterial effect and can effectively prevent and treat various diseases caused by bacterial infections. Its appearance attracted significant attention from medical staff, and it was soon successfully manufactured into a drug in the 1940s and widely used in clinical practice. The advent of penicillin brought great hope to the medical community, but it also brought some unexpected problems. Due to the strong antibacterial effect of penicillin, medical staff began to pay less attention to sterilization technology, believing that the infection problem could be solved by using antibiotics (Nathwani and Wood, 2012). This concept weakened the intensity of HAI control to a certain extent and led to the outbreak of some HAIs. At the same time, the abuse of antibiotics has also led to the emergence of multi-drug resistance

(MDR) in bacteria.

The resistance mechanism of this type of bacteria is not natural inherent resistance but acquired resistance, which is related to the intensity of antibacterial drug use (Fish et al., 1995). In just over a decade after the first antibiotic was discovered, there were cases of resistant strains of antibiotics such as penicillin (Rosenblatt-Farrell, 2009). Over time, the focus on multidrug-resistant bacteria has gradually increased. By the 1970s and 1980s, multidrug-resistant bacteria had become a severe public health problem, and medical institutions had to face the challenge of infection control (Rosenblatt-Farrell, 2009). However, the problem of multidrug-resistant bacteria has intensified over the past few decades, especially with the increasing abuse of antibiotics worldwide. The development of multidrug-resistant bacteria has become more prominent and worrying. This has led medical staff to re-examine the importance of HAI control and turn their attention back to aseptic techniques. They realized that although antibiotics were essential in preventing and treating infections, aseptic techniques were still the key to preventing HAIs. Therefore, they began to combine aseptic techniques with antibiotic application to solve the problem of infection and HAI more effectively (Dellinger, 2016; Najjar and Smink, 2015). This shift marked the further maturity and progress of the antibiotic era. Medical staff began to pay more attention to comprehensive measures for HAI control, including strengthening disinfection work in medical environments such as operating rooms and wards, improving medical staff's awareness of aseptic operations, and the rational use of antibiotics. These measures

together form the basis of the modern HAI control system.

2.1.4 Post-pandemic Era: Re-emerging Challenges for HAI Management

The fourth stage of HAI management: post-epidemic era. With the gradual control of the COVID-19 pandemic worldwide, countries have realized that global infection prevention and control management has entered the post-epidemic era (Yang et al., 2021) . In the post-epidemic era, HAI management faces many challenges. First, due to the tense epidemic, medical institutions' infection prevention and control measures may be relaxed, resulting in an increased risk of infection. Secondly, with the control of the epidemic, the pressure on medical resources has gradually eased. However, the medical staff may pay less attention to infection prevention and control, increasing the risk of infection. In addition, the post-epidemic era may also face the emergence and spread of new pathogens, which will bring new challenges to infection management. Despite the global experience gained during the recent pandemic, scholars have highlighted that many countries are still not adequately equipped to handle the next epidemic. (Clark et al., 2022; Frieden et al., 2021; Frutos et al., 2021; Milojević, 2021) . In 2018, some scholars conducted a global assessment of the ability of various countries to detect and respond to infectious disease events. Among them, Europe and North America have the most adequate prevention, while the countries with the least adequate prevention are Central Africa, West Africa, and Southeast Asia (Oppenheim et al., 2019). At the same time, it is essential to strengthen preparedness for a potential outbreak of

Disease X (van Kerkhove et al., 2021). As early as 2019, WHO announced the top ten global health threats in 2019. Among them, drug-resistant superbugs, global influenza, high-risk viruses such as Ebola, and weak primary health care are highly related to the field of HAI management. These also represent ongoing challenges that must be addressed (World Health Organization, 2019).

Although the post-epidemic era is full of challenges, it also brings new opportunities for HAI management. First, the practical experience and lessons learned during the epidemic provide valuable data and infection management cases, which helps improve and optimize the infection management system. Secondly, in the post-epidemic era, medical institutions and medical staff will pay more attention to infection prevention and control, which will help to form a better infection prevention and control atmosphere. In addition, with the continuous advancement of science and technology, new infection prevention and control technologies and methods will continue to emerge, providing new solutions for infection management. To address emerging challenges and capitalize on opportunities in the post-pandemic era, it is essential to adopt effective HAI management strategies. Strengthen the implementation and supervision of infection prevention and control measures to ensure that various measures are effectively implemented. Thoroughly assess the job competency of professionals, strengthen the training and education of medical staff, and improve their awareness and skills of infection prevention and control. In addition, strengthening international cooperation and exchange is essential to jointly address global infection challenges. With medical technology's continuous