

Risk Factors of Healthcare-associated Infections Among Pediatric Hospitalized Patients in Chinese General Hospitals From 2001 to 2020: A Systematic Review and Meta-Analysis

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Abstract

Background: Healthcare-associated infections (HAIs) have been an increasing global public health threat to the globe. Paediatric hospitalized patients are particularly to HAIs and the identification of risk factors is essential to help policy-makers and hospital managers to develop prevention and control strategies. This study aims to determine the risk factors associated with HAIs among paediatric hospitalized patients in Chinese general hospitals.

Methods: Medline, EMBASE and Chinese Journals Online databases were searched. The search was limited to studies published from January 1st 2001 and December 31st 2020. Meta-analyses of OR in the prevalence were estimated. Heterogeneity between studies was assessed based on the B^2 and I^2 statistics to select the meta-analysis model. Reviewer Manager 5.3 was employed and $P < 0.05$ was considered as the statistical significance.

Results: 205 published articles were searched from the databases, in which 25 studies were included in the quantitative synthesis and meta-analysis for the risk factors of HAIs among paediatric hospitalized patients in Chinese general hospitals. 61,773 paediatric patients were incorporated in the included studies, which covered 13 regions in 10 provinces in China. Of them, 2,438 paediatric patients had HAIs. The meta-analyses showed that the ORs of younger age (2.25[1.32-3.85]), hormone (3.66[1.73-7.74]), invasive procedures (5.62[4.27-7.40]), longer hospitalization stay (7.79[6.38-9.50]), malnutrition (3.72,[1.80-7.70]), over 3 kinds of antibiotics (3.25,[2.66-3.96]), over 3 kinds of underlying disease (4.24[1.84-9.78]), large room (2.22[1.28-3.85]), and autumns and winter (1.56[1.04-2.35]) were the independent risk factors that had a negative impact on HAIs with a statistical significance ($P < 0.05$).

Conclusions: Under the age of 1 year, application of hormone, experiencing invasive procedure, hospitalization stay more than 7 days, malnutrition, using more than 3 kinds of antibiotics, beyond 3 kinds of underlying disease, large room, and autumn and winter were the main risk factors associated with the higher prevalence of HAIs among paediatric hospitalized patients in Chinese general hospitals. This provided the evidence base to inform the policy-makers and hospital managers. The confirmed successful and cost-effective prevention and control measures need to be adopted to reduce the occurrence of HAIs.

Introduction

Healthcare-associated infections (HAIs) have been an increasing global public health threat to the globe, taking place in a hospital setting after patients are admitted to the hospital more than 48 hours (1, 2). Evidence has shown that HAIs have not only increased the mortality, morbidity and prolonged hospitalization for the patients, especially when the antimicrobial resistant microorganisms caused HAIs, but also led to high economic burden for the whole society (3, 4). China is certainly affected by HAIs and has reported that HAIs could result in the direct economic burden around ¥ 10 to 15 billion (5). Besides, a study conducted in 68 Chinese hospitals estimated that HAIs increased the hospitalization stay of 10.4 days (6). It is essential to take cost effective measures to reduce the presence of HAIs, such as the surveillance system of HAIs and China has established the National Nosocomial Infection Surveillance System.

As the increasing number of the special susceptible populations, paediatric hospitalized patients are particularly vulnerable to HAIs, due to their internal characteristics and external factors such as immature immune systems, immuno-deficiencies, total parenteral nutrition, congenital malformations, and stay in an intensive care (ICU) (7, 8). A study undertaken in the developing countries showed that the incidence of HAIs in neonate intensive care (NICU) is nearly 30% and is responsible for 4–56% of all causes of reported neonatal deaths (9, 10). Specially, the prevalence of HAIs was reported with a range from 10 to 25 % in paediatric intensive care (PICU) in China (11, 12).

Current literature has confirmed that up to 70% of HAIs cases could be preventable (13, 14). This shows that the identification of the risk factors on HAIs is essential to help the policy-makers and hospital managers to develop the prevention and control strategies and allocate the relevant resources to protect the susceptible hospitalized patients, resulting in the reduction on the occurrence of HAIs (15). However, limited risk factor analysis studies on HAIs among paediatric hospitalized patients have been conducted only in individual hospitals and no comprehensive study is yet to be undertaken in China. Therefore, our systematic review and meta-analysis aims to determine the risk factors associated with HAIs among paediatric hospitalized patients in Chinese general hospitals, which are different from specialty hospitals.

Methodology

Systematic search strategy

The PICO/S (Population, Intervention, Comparison, Outcome, and Study type) tool was applied to define the scope of the literature. The specific details are as follows.

Population: paediatric hospitalized patients admitted to the hospitals more than 48 hrs

Intervention: healthcare-associated infections diagnosed by the criteria reported by the Chinese National Nosocomial Infections Surveillance System

Comparison: paediatric hospitalized patients without healthcare-associated infections

Outcome: HAIs prevalence

Study type: cross-sectional study, case-control study or cohort study

This systematic review and meta-analysis was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. Medline, EMBASE and Chinese Journals Online databases (China National Knowledge Infrastructure [CNKI], Chinese Wan Fang digital database and Chinese Science and Technique Journals Database [VIP]) were selected to search the relevant literature. The studies published were limited between 1st January 2001 and 31st December 2020.

Chinese corresponding search terms in the title, abstract and keywords included healthcare-associated infections/cross infections/hospital acquired infections/nosocomial infections, risk factors/influencing factors, paediatric department/children/adolescent and China for the Chinese databases (CNKI, Wan Fang,

and VIP). As to Medline and EMBASE, the medical subject heading (MeSH) terms in keywords were adopted, including “cross infection” AND “risk factors” AND “paediatrics” OR “children” OR “adolescent” OR “child” OR “paediatrics” AND “China”.

Inclusion and exclusion criteria

The inclusion criteria were as follows: 1) risk factors analysis with a case-control, cohort or cross-sectional study; 2) a multi-centre study or a single-centre study; 3) study language being either English or Chinese; 4) general hospital(s) (non-speciality hospitals); 5) any study published between 1st January 2001 and 31st December 2020.

The exclusion criteria were as follows: 1) conference papers or editorials/letters; 2) duplicate studies and repeated data published in different journals or in theses and journals concomitantly; 3) any study outside China; 4) any study reporting only on specific hospital units rather than overall hospital setting (e.g. neurosurgery) or disease (e.g. pneumonia) or infection type (e.g. ventilator-associated pneumonia); 5) only description on the prevalence or landscape of HAIs; 6) risk factors concluded without any statistical inference (e.g. only description or summary) and only based on the researchers' perspective.

Data abstraction

Three independent reviewers (D.Y., L. C. and X.L.) searched the relevant published articles on risk factors for HAIs among paediatric hospitalized patients from the included databases. Initial screening of the searched published articles was conducted by screening the titles, abstracts and keywords. The eligibility for the articles was scrutinized by reading the full text according to the inclusion and exclusion criteria. The eligibility for 10% of the included studies screened by each reviewer was checked again by other two reviewers to determine whether it was appropriate. Disagreement on the included studies was dealt with based on the discussion within the three reviewers.

Quality assessment

The JBI' (Joanna Briggs Institute) critical appraisal tools were employed to assess the quality of the included studies conducted by the three reviewers (D.Y., L. C. and X.L.) (16). This tool includes 8 questions to identify the quality of a cross-sectional study, 10 questions to determine the quality of a case-control study, and 11 questions to assess the quality of a cohort study. For each question, there are 4 options to choose (Yes, Unclear, No and Not applicable). The less the number of a positive option (Yes) is, the more the uncertainty of a study is. Otherwise, the quality of a study is better. Besides, 0–2 points were assigned to each question. That is, 'Yes' is equal to 2 points; 'Unclear or Not applicable' is equal to 1 point; and 'No' is equal to 0. Therefore, the higher scores of a study get, the better quality of this study is.

Statistical analysis

Review Manager 5.3 software was deployed to estimate the risk factor odds ratio (OR) to show the level of risk that each factor between the HAIs pediatric hospitalized patients and the pediatric hospitalized patients without HAIs. Moreover, the forest plot was applied to show the results of the pooled OR of each risk factor. Heterogeneity between studies was assessed based on the $\hat{\tau}^2$ and I^2 statistics to select the meta-analysis model. When results had a $\hat{\tau}^2$ ($P \leq 0.05$) and/or $I^2 > 50\%$, data were considered heterogeneous and the

random-effects model was used; otherwise, the fixed-effects model was used. $P < 0.05$ was set as the statistical significance.

Results

Characteristics of the eligible studies from the database search

Figure 1 exhibits that generally, 205 published articles were screened from the database search. After screening the full text with the inclusion and exclusion criteria, 15 publications were included in the quantitative synthesis and meta-analysis for the risk factors associated with the HAIs prevalence among paediatric hospitalized patients.

Table 1 presents that totally, 61,773 paediatric hospitalized patients were included in the 15 included studies, which covered 13 regions in 10 provinces of China. Specifically, 2,438 patients were identified as having HAIs, while 59,335 patients did not have HAIs. The majority (11/15) of the included studies were retrospective cross-sectional studies; 2 studies were retrospective case-control studies; one was retrospective cohort study; and one was retrospective and prospective study. Besides, most of the studies (9/15) were conducted in tertiary hospitals, while the rest were undertaken in secondary hospitals.

Frequency of the identified risk factors from the included studies

Table 2 shows a total of 20 risk factors on HAIs were identified from the 15 included studies. The most frequent risk factors were length of hospitalization (14/15), age (10/15), gender (5/15) and number of kinds of antibiotics use (5/15). The risk factors were not incorporated in the meta-analyses since the frequency was less than 2. In addition, although the classification of the age and length of hospitalization was different among the included studies, we adopted the most frequent classification used in the included studies for the meta-analyses. With regard to the length of time of antibiotics use, due to the inconsistent classification used in both studies (17, 18), it was also excluded in the meta-analysis.

Quality assessment of all the included studies

With regard to the 13 cross-sectional studies, the median points were 10 (medium points). It indicated the overall quality of the cross-sectional studies was fair, which needed to be improved. All of the studies clearly defined the inclusion for the pediatric hospitalized patients and set the outcomes measured in a valid and reliable way. However, some of the cross-sectional studies needed to be improved in study design, including describing the study setting in more detail, providing the specific definition and inclusion and exclusion criteria for the HAIs pediatric hospitalized patients etc. Only two case-control and one cohort studies were included in this systematic review. The overall quality of the case-control studies was good since one study got 17 points, while the other study got 18 points. Both of them also needed to provide the clear information about the outcome measurements and how to measure the exposure. The quality of the cohort study was poor (10 points). It did not clearly depict the follow-up time and how to deal with the incomplete follow-up. Also, it did not provide the clear information about the outcome measurements and how to measure the exposure. Quality assessments of the included studies are exhibited in Supplementary material (Appendix 1: Table 1, 2, and 3).

Meta-analyses of the included risk factors

Table 3 presents the pooled ORs of the risk factors estimated in the meta-analyses between the paediatric hospitalized patients with HAIs and the paediatric hospitalized patients without HAIs. 11 risk factors were analysed in the meta-analysis. Specific information is as follows. The forest plots of the included risk factors are shown in Supplementary material (Appendix 2: Figure 1-1 to 1-11).

Age (≤ 1 year vs. >1 year): 6 studies (17, 19-23) reported the age (≤ 1 year) of 429 with and 6,001 patients without HAIs. The random-effects model showed that the prevalence of HAIs was significantly higher ($P=0.003$) in patients who were younger than 1 year old compared with those who were over 1 year old (OR: 2.25, 95% CI: 1.32-3.85). There was a high heterogeneity among the studies ($I^2=0.35$ ($P<0.01$), $I^2=84\%$).

Gender (Male vs. Female): 6 studies (17-19, 22, 24, 25) reported the gender of 790 with and 15,289 patients without HAIs. The fixed-effects model showed that the prevalence of HAIs was almost equal ($P=0.26$) between male and female patients (OR: 1.07, 95% CI: 0.95-1.21). The heterogeneity did not exist among the studies ($P=0.63$, $I^2=0\%$).

Hormone: 2 studies (17, 18) reported the hormone of 25 with and 31 patients without HAIs. The fixed-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0007$) in patients using hormone than those not using hormone (OR: 3.66, 95% CI: 1.73-7.74). The heterogeneity did not exist among the studies ($P=0.61$, $I^2=0\%$).

Invasive procedures: 4 studies (17, 21, 26, 27) reported the invasive procedures of 191 with and 1,183 patients without HAIs. The fixed-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients experiencing invasive procedure than those not experiencing invasive procedure (OR: 5.62, 95% CI: 4.27-7.40). The heterogeneity did not exist among the studies ($P=0.77$, $I^2=0\%$).

Length of hospitalization (>7 days vs. ≤ 7 days): 12 studies (17, 19-25, 28-31) reported the length of hospitalization (> 7 days) of 1,617 with and 12,534 patients without HAIs. The random-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients whose hospitalization were more than 7 days than those whose hospitalization were less than 7 days (OR: 7.79, 95% CI: 6.38-9.50). There was a middle level of heterogeneity among the studies ($I^2=0.06$ ($P=0.001$), $I^2=64\%$).

Malnutrition: 2 studies (17, 18) reported the malnutrition of 29 with and 54 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0004$) in patients with malnutrition than those without malnutrition (OR: 3.72, 95% CI: 1.80-7.70). The heterogeneity did not exist among the studies ($P=0.75$, $I^2=0\%$).

Number of kinds of antibiotics (>3 vs. ≤ 3): 6 studies (17, 18, 20, 22, 28, 31) reported the number of kinds of antibiotics (> 3) of 177 with and 1,206 patients without HAIs. The fixed-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients who used more than 3 kinds of antibiotics than those who used at most 3 kinds of antibiotics (OR: 3.25, 95% CI: 2.66-3.96). The heterogeneity did not exist among the studies ($P=0.15$, $I^2=39\%$).

Number of underlying disease (>3 vs. ≤3): 4 studies (17, 21, 31) reported the number of underlying disease (> 3) of 68 with and 79 patients without HAIs. The random-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0002$) in patients who had more than 3 kinds of underlying disease than those who had at most 3 kinds of underlying disease (OR: 4.24, 95% CI: 1.84-9.78). The heterogeneity existed among the studies ($I^2=0.30$ ($P=0.11$), $I^2=55%$).

Room size (Large vs. Small): 2 studies (19, 23) reported the room size (Big) of 77 with and 1,061 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P=0.005$) in patients who stayed in a large room than those who stayed in a small room (OR: 2.22, 95% CI: 1.28-3.85). The heterogeneity did not exist among the studies ($P=0.72$, $I^2=0%$).

Seasons (Autumn + Winter vs. Spring + Summer): 4 studies (19, 20, 23, 32) reported the seasons (Autumn + Winter) of 235 with and 6,145 patients without HAIs. Random-effects model showed that the prevalence of HAIs was significantly higher ($P=0.03$) in patients who were admitted to the hospitals in autumn or winter than those who were admitted to the hospitals in spring or summer (OR: 1.56, 95% CI: 1.04-2.35). The heterogeneity existed among the studies ($I^2=0.11$ ($P=0.02$), $I^2=69%$).

Use of antibiotics: 6 studies (20, 22, 24, 26, 28, 31) reported the use of antibiotics of 788 with and 20,957 patients without HAIs. Random-effects model showed that the prevalence of HAIs was higher ($P=0.09$) in patients using antibiotics than those not using antibiotics (OR: 3.18, 95% CI: 0.83-12.15). There was a high heterogeneity among the studies ($I^2=1.87$ ($P<0.01$), $I^2=85%$).

Discussion

Our systematic review and meta-analysis first provided the pooled ORs of the risk factors associated with the higher HAIs prevalence among the paediatric hospitalized patients in Chinese general hospitals, which covered 61,773 paediatric hospitalized patients were included in the 15 included studies distributing 13 regions in 10 provinces of China. Of them, 2,438 patients were identified as having HAIs. Besides, our study shows that age, gender, hormone, invasive procedures, length of hospitalization, malnutrition, number of kinds of antibiotics, number of underlying disease, room size, and seasons were the independent risk factors associated with the higher HAIs prevalence among the paediatric hospitalized patients with a statistical significance ($P < 0.05$). Our findings could provide the evidence bases to develop the personalised prevention and control measures to reduce the HAIs occurrence among paediatric hospitalized patients in China.

Our review found that paediatric hospitalized patients under the age of 1 year were at higher risk to get HAIs than those beyond the age of 1 year. This is similar to another study carried out in Pennsylvania among paediatric healthcare-associated pneumonia, which showed that children who were younger than 1 year were the most cases (33, 34). Among the children patients below the age of 1 year, particularly the neonates (age ≤ 30 days), due to the increasing number of low weight children, preterm infants, and critically ill children, they are more hazardous to acquire HAIs, especially those in NICU (35). Jansen et al. recommended that human milk feeding is one of the cost effective measures to reduce the likelihood of getting HAIs, because human milk feeding contains numerous substances and bioactive compounds with putative antimicrobial

actions, thus decreasing the risk of acquiring HAIs (1). Furthermore, the neonates should be set as the particular high-risk patients given special protective measures.

Application of hormone, malnutrition, and presence of more than 3 kinds of underlying disease among paediatric hospitalized patients was found as main risk factors for acquiring HAIs in our review. Although hormone, especially glucocorticoid, could resist virus, inflammation, and allergy and so on, the long-term use of hormone severely impairs the children's growth and development, and internal secretion, thus increasing the chance of getting HAIs (21). Nutrition is one of the ways to build up the children's immune systems, thereby increasing the resistance to HAIs (36). However, the underlying disease increases the susceptibility of paediatric hospitalized patients, so that they are more prone to getting secondary infections due to the reduction of the patients' immune response (3, 37).

Our review also found that paediatric hospitalized patients with invasive procedure were over 5 times more hazardous to obtain HAIs than their counterparts. Many studies have reported that invasive procedure, such as surgery, mechanical ventilation, and central venous catheter and so on increased the risk of obtaining HAIs among paediatric hospitalized patients (11, 38). The hazard of getting HAIs among paediatric hospitalized patients staying in hospital more than 7 days was over 7 times higher than their counterparts. This finding is consistent to the current literature (3, 11). The prolonged hospitalization stay increases the likelihood of acquiring HAIs, whereas the presence of HAIs also extends the hospitalization stay, which is a positive association (23). This further aggravates the difficulty of treatment of the disease and augments the medical expenditure.

The risk of acquiring HAIs in paediatric hospitalized patients who used more than 3 kinds of antibiotics were over 3 times higher than those using less than 3 kinds of antibiotics, which is consistent with the study conducted among paediatric hospitalized patients with multi-drug resistant infection in PICU (11). Multiple varieties of antibiotics applied in paediatric hospitalized patients change the children's physiology and biochemistry, leading to weakening the children's immune system to the bacteria (11, 39). This can increase the risk of obtaining HAIs. The United States has acknowledged that the antimicrobial treatment is the most sensitive proxy indicator for the presence of HAIs (40). This indicates that the clinical doctors need to be prudent when giving antibiotics prescription to the paediatric hospitalized patients. Overuse of antibiotics is associated with the presence of antimicrobial resistance (AMR), which further impairs the patients' safety (4).

Paediatric hospitalized patients staying in a large ward and admitted to the hospitals in autumn or winter were more likely to acquire HAIs than their counterparts suggested by our review. On one hand, children need to be cared for by their parents or guardians when they are in hospital, which results in quite frequent visits, especially in a large paediatric room (23). Therefore, this leads to increasing the occurrence of cross infection. Frequent disinfection based on the perfect execution, decreasing visits to the wards and effective isolation measures are necessary for the reduction of HAI among paediatric hospitalized patients. On the other hand, healthcare-associated respiratory infections are the most common HAIs in paediatric inwards, which happens more frequently in autumn and winter. Therefore, it is essential to contain HAIs in autumn and winter.

After completing the identification of the risk factors associated with higher HAIs prevalence among paediatric hospitalized patients, it is necessary to adopt corresponding prevention and control measures to reduce the occurrence of HAIs, thus decreasing the mortality, morbidity and economic burden for patients and the whole society. Generally, a number of evidence-based prevention and control measures are recommended in current studies and have been confirmed successful (1). For example, washing hands is supposed to be the easiest cost-effective measure to decrease the risk of HAIs. Jansen et al. have recently suggested that quality improvement on cooperation and benchmarking is most promising for reduction in HAIs. Identifying and implementing the best practices, and selecting the quantitative measurements are two of the examples recommended in this study (1).

Our systematic review and meta-analysis has some limitations as well. First, our systematic review only included the Chinese general hospitals. Other types of hospitals, like speciality hospitals were excluded. Therefore, the whole picture of the risk factors for HAIs among paediatric hospitalized patients in China is not yet to be shown in this review. Second, present included studies lack quality in study design. It calls for a more comprehensive study design to conduct the similar study in the future in China.

Conclusions

Under the age of 1 year, application of hormone, experiencing invasive procedure, hospitalization stay longer than 7 days, malnutrition, using more than 3 kinds of antibiotics, beyond 3 kinds of underlying disease, large room, and autumn and winter were the main risk factors associated with the higher prevalence of HAIs among paediatric hospitalized patients in Chinese general hospitals. This provided the evidence base to inform the policy-makers and hospital managers when developing prevention and control strategies. The confirmed successful and cost-effective prevention and control measures need to be adopted to reduce the occurrence of HAIs.

Declarations

Ethics approval and consent to participate

It is not applicable.

Consent for publication

It is not applicable.

Availability of data and materials

The datasets and materials analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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It is not applicable.

Authors' contributions

C.Y. was in charge of the whole systematic review and meta-analysis. D.Y., L. C. and X.L. searched the relevant published articles from the databases and determined the quality of the included studies. D.Y., L. C. and C.Y. designed the systematic review framework. D.Y., L. C. and C.Y. drafted and revised the review manuscript. X.L. provided the comments to the manuscript and proofed the manuscript.

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Tables

Table 1 Characteristics of the included studies on risk factors for healthcare-associated infections among paediatric hospitalized patients in Chinese general hospitals from 2001 to 2020

Study ID	Author (Year)	Study design	Region (Province)	Study setting	Year begun and duration (years)	Number of participants	
						HAls	Non-HAls
1	Chen (2017) (19)	Retrospective Cross-sectional	Neijiang (Sichuan)	One tertiary hospital	2015, 1	34	566
2	Zhou (2018) (31)	Retrospective Cross-sectional	Beijing	One secondary hospital	2011, 5	48	1,844
3	Xu (2018) (21)	Retrospective Case-Control	Hangzhou (Zhejiang)	One tertiary hospital	2017, 1	30	30
4	Wei (2013) (26)	Retrospective Cross-sectional	Yuyao (Zhejiang)	One secondary hospital	2004, 8	60	4,170
5	Yu et al. (2006) (25)	Retrospective Cohort	Shanghai	One tertiary hospital	2003, 2	850	17,811
6	Li & Tang (2010) (32)	Retrospective Cross-sectional	Neijiang (Sichuan)	One tertiary hospital	2008, 2	125	5,183
7	Chen (2005) (20)	Retrospective Cross-sectional	Xianju (Zhejiang)	One secondary hospital	2001, 3	173	5,353
8	Zhao (2009) (22)	Retrospective Cross-sectional	Changsha (Hunan)	One tertiary hospital	2006, 3	201	4,839
9	Huang et al. (2008) (28)	Retrospective and Prospective Cross-sectional	Fuzhou (Jiangxi)	One tertiary hospital	2005, 3	305	7,374
10	Sun et al. (2012) (29)	Retrospective Cross-sectional	Wenxi (Shanxi)	One secondary hospital	2008, 3	165	4,649
11	Tan (2009) (30)	Retrospective Cross-sectional	Shanghai	One secondary hospital	2005, 2	215	4,299
12	Wang (2008) (17)	Retrospective Case-Control	Tongling (Anhui)	One tertiary hospital	2003, 3	105	105
13	Zheng et al. (2014) (23)	Retrospective Cross-sectional	Tangshan (Hebei)	One tertiary hospital	2012, 1	59	980
14	Yang et al. (2016) (24)	Retrospective Cross-sectional	Wenzhou (Zhejiang)	One tertiary hospital	2010, 5	56	1,944

15	Jiang (2020) (18)	Retrospective Cross-sectional	Dali (Yunnan)	One secondary hospital	2017, 2	12	188
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Table 2 Frequency of the identified risk factors in the included studies on risk factors for healthcare-associated infections among paediatric hospitalized patients in Chinese general hospitals from 2001 to 2020

Study ID/Risk factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Age	√		√	√		√	√	√				√	√	√	√	10
Apgar scores												√				1
Gender	√						√					√		√	√	5
Hormone												√			√	2
Hypoxic-ischemic encephalopathy (HIE)												√				1
Infection when admitted															√	1
Invasive procedure			√	√								√				3
Length of hospitalization	√	√	√	√		√	√	√	√	√	√	√	√	√	√	14
Length of time of antibiotics use												√			√	2
Malnutrition												√			√	2
Neonatal asphyxia												√				1
Number of kinds of antibiotics		√				√	√					√			√	5
Number of underlying disease		√	√									√				3
Pneumonia												√				1
Premature												√				1
Room size	√												√			2
Seasons	√				√	√							√			4
Stay in ICU												√				1
Tracheal cannula														√		1
Use of antibiotics			√	√										√		3

Table 3 The pooled ORs of the risk factors estimated in the meta-analyses between the patients with HAIs and the patients without HAIs among paediatric hospitalized patients

Risk factors	Number of patients		Meta-analysis model	OR [95% CI]	$z(P)$	β (%)	P -value
	HAls	Non-HAls					
Age (≤ 1 year vs. > 1 year)	602	11,873	Random-effects	2.25 [1.32-3.85]	0.35 (< 0.01)	84	0.003*
Gender (male vs. female)	1,258	25,453	Fixed-effects	1.07 [0.95-1.21]	-	0	0.26
Hormone	117	293	Fixed-effects	3.66 [1.73-7.74]	-	0	0.0007*
Invasive procedure	117	293	Fixed-effects	5.62 [4.27-7.40]	-	0	0.0007*
Length of hospitalization (≥ 7 days vs. < 7 days)	2,241	49,794	Random-effects	7.79 [6.38-9.50]	0.06 (0.001)	64	< 0.01 *
Malnutrition	59	235	Fixed-effects	3.72 [1.80-7.70]	-	0	0.0004*
Number of kinds of antibiotics (> 3 vs. ≤ 3)	844	19,703	Fixed-effects	3.25 [2.66-3.96]	-	39	< 0.01 *
Number of underlying disease (> 3 vs. ≤ 3)	183	1,979	Random-effects	4.24 [1.84-9.78]	0.30 (0.11)	55	0.0007*
Room size (large vs. small)	93	1,546	Fixed-effects	2.22 [1.28-3.85]	-	0	0.005*
Seasons (Autumn + Winter vs. Spring + Summer)	391	12,082	Random-effects	1.56 [1.04-2.35]	0.11 (0.02)	69	0.03*
Use of antibiotics	843	25,524	Random-effects	3.18 [0.83-12.15]	1.87 (0.01)	85	0.09

Note: * means the statistical significance at $P < 0.05$.

Figures

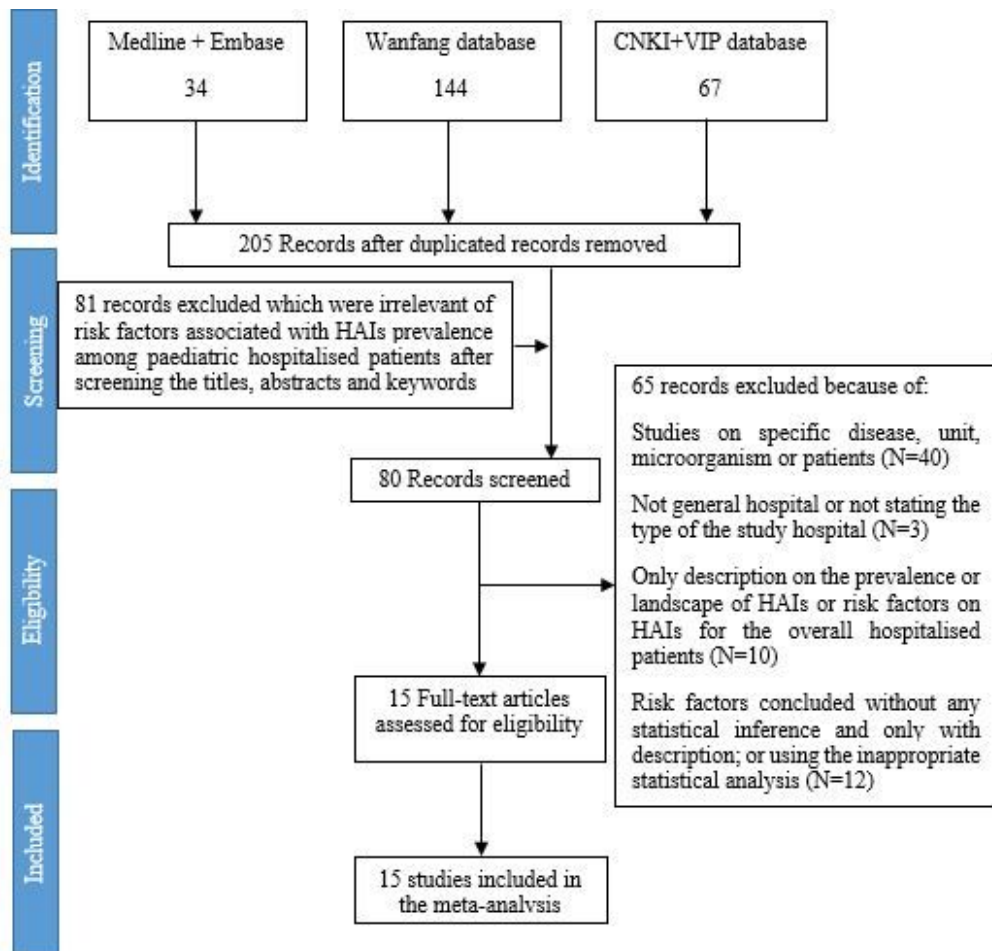


Figure 1

Flow diagram of literatures search from the databases Note: Abbreviations: CNKI: China National Knowledge Infrastructure; Wangfang database: Chinese Wan Fang digital database; VIP: Chinese Science and Technique Journals Database; HAIs: Healthcare-associated infections.

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