Risk Factors on Healthcare-Associated Infections Among Hospitalized Tuberculosis Patients in China From 2001- 2020: A Systematic Review and Meta-Analysis

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Abstract

Background

As a chronic communicable disease, tuberculosis (TB) is acknowledged as a global public health issue. A comprehensive analysis of risk factors on HAIs among TB hospitalized patients in Chinese hospitals is vacant. The aim of this systematic review and meta-analysis is to investigate the risk factors associated with healthcare-associated TB in Chinese 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 ORs in the prevalence were estimated. Heterogeneity between studies was assessed based on the τ^2 and I^2 statistics to select the meta-analysis model. Review Manager 5.3 was employed and $P < 0.05$ was considered as the statistical significance.

Results

The databases searched 418 records, of which 11 published articles were included in the quantitative meta-analysis. A total of 11,922 TB hospitalized patients were included in the systematic review and meta-analysis, of which 1,133 were diagnosed as having HAIs. Older than 65 years (OR: 2.89[2.01-4.15]), presence of complication (OR: 3.28[2.10-5.13]), presence of diabetes mellitus (OR: 1.63[1.22-2.19]), invasive procedure (OR: 3.80[2.25-6.42]), longer than 15 days of hospitalization stay (OR: 2.09[1.64-2.64]), secondary tuberculosis (OR: 2.25[1.48-3.42]), smoking (OR: 1.40[1.02-1.93]), presence of underlying disease (OR: 2.66[1.53-4.62]), and use of antibiotics (OR: 2.77[2.35-3.27]) were the main risk factors associated with higher HAIs prevalence among TB hospitalized patients with a statistical significance ($P < 0.05$).

Conclusions

older than 65 years, presence of complication, presence of diabetes mellitus, invasive procedure, longer than 15 days of hospitalization stay, secondary tuberculosis, smoking, presence of underlying disease, and use of antibiotics were the main risk factors which had a negative impact on HAIs among TB hospitalized patients in Chinese hospitals. These findings provided evidence for the policy makers and hospital managers to make effective infection prevention and control measures to constrain the rising of HAIs. It is also required that more cost-effective infection prevention and control measures should be widely applied in routinely medical treatment and clinical management to healthcare-associated TB.

Introduction

As a chronic communicable disease, tuberculosis (TB) is acknowledged as a global public health issue, because it is one of the 10 top causes of disability and a leading cause of death globally (1). In 2019, the

World Health Organization (WHO) reported that around 10.0 million people were infected with TB and 1.4 million died in 198 countries and territories (2). Particularly, China had the third highest burden of TB in the world and 8.4% of all global cases were detected in China (2). Since the pandemic of COVID-19 is threatening the globe, it reverses the deduction on TB incidence by having a negative impact on the Gross Domestic Product (GDP) per capita and undernutrition, which are two key determinants of TB incidence. The WHO estimated that TB cases could increase by more than 1 million per year in the period 2020-2025 because of the COVID-19 pandemic (2). This exacerbates the situation of diminishing TB.

Hospitals, as the main body to provide health care to treat TB, are also the main repository of healthcare-associated infections (HAIs). HAIs are an adverse outcome during providing health care to patients in hospitals. It affects patients' safety and extends the hospitalization, thereby patients suffering from the increasing morbidity and mortality (3, 4). HAIs are also a global public health problem. In 2011, the WHO conducted a literature review and indicated that 7 and 10 out of every 100 hospitalized patients had a HAI in high-income countries and middle-income countries respectively (5, 6). The HAIs prevalence in China was estimated around 3 out of every 100 hospitalized patients in 2018 (7). Although it was lower than that reported by the WHO, China has the largest population in the world. This still indicates China has a high burden attributable to HAIs.

Usually, a TB patient needs to be treated with multiple antibiotics for 6 to 12 months (3). This results in a long time exposure to antibiotics for patients. Antibiotics use in many studies has been recognised as one of the risk factors to increase HAIs incidence (8, 9). As for TB patients themselves, especially the elderly, they have a low immunity to fight against the infection (10). As a consequence, TB patients are at high risk to get HAIs. Therefore, it is essential for health professionals and managers to understand what kind of risk factors have an impact on healthcare-associated TB. Thus, it can contribute to guideline and regulation about constraining healthcare-associated TB in hospitals.

Several studies investigating the potential risk factors on healthcare-associated TB have been conducted in China. However, all of them were based on a single hospital, which is sporadic. There is still scarce evidence-based guideline or regulation to help health professionals and hospital managers to increase the awareness of the hazards of healthcare-associated TB and take effective infection control measures to constrain the occurrence of healthcare-associated TB. The aim of this systematic review and meta-analysis is to investigate the risk factors associated with healthcare-associated TB between patients with HAIs and those without HAIs in Chinese 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.

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

Intervention: healthcare-associated infections (diagnosed by the definition proposed by the Ministry of Health, People's Republic of China (11))

Comparison: hospitalized TB patients without HAIs

Outcome: HAIs prevalence

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

This systematic review was conducted corresponding to 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 searched. The studies published were limited from 1st January 2001 to 31st December 2020, since the version of diagnosis of HAIs was published in 2001 in China.

Search Chinese corresponding terms in the title, abstract and keywords included healthcare-associated infections/cross infections/hospital acquired infections/nosocomial infections, tuberculosis, risk factors/influencing factors/ and China for the Chinese databases. The logical word is "AND". As to Medline and EMBASE, medical subject heading (MeSH) terms in key words were adopted. The MeSH terms were ("cross infection" AND "tuberculosis" AND "risk factors" AND "China").

Inclusion and exclusion criteria

The inclusion criteria were as follows: 1) risk factors analysis by using a case-control or cohort study; 2) a multi-centre study or a single-centre study; 3) study language being either English or Chinese.

The exclusion criteria were as follows: 1) conference papers or editorials/letters; 2) duplicate studies and repeated data published in different journals concurrently; 3) any study outside China; 4) only description on the prevalence or landscape of HAIs; 5) risk factors concluded without any statistical inference (e.g. according to the clinical experience).

Data abstraction

Two independent reviewers (X.L. and N.R.) screened the obtained literature by title and abstract to determine the eligibility of studies. Potential disagreement was resolved by discussion. Identified studies were retrieved in full text and were checked again for eligibility. In case of exclusion of the study the reason was documented. Moreover, cross-references were also considered by screening the bibliography of eligible studies as well as bibliography of cross-references.

Quality assessment of the included studies on risk factors for HAIs among TB hospitalized patients

X.L. and N.R. jointly assessed the quality of the included studies for risk factors analysis associated with HAIs among TB hospitalized patients according to the criteria of JBI' (Joanna Briggs Institute) critical

appraisal tools (12). This tool includes 8 questions to identify the quality of a cross-sectional 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. Moreover, a value was assigned to each answer in order to calculate the scores for each study, that is, 2 points for 'Yes', 1 point for 'Unclear or Not applicable', and 0 point for 'No'.

Statistical analysis

Review Manager 5.3 software was deployed to assess the risk factor odds ratio (OR) among TB hospitalized patients. Meta-analyses of OR in HAI prevalence were performed. 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 $\hat{\tau}^2$ ($P < 0.05$) 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 considered as a statistical significance.

Results

Characteristics of eligible studies

Figure 1 shows that totally, 851 records were searched from the included databases. Eventually, 11 published articles were incorporated in the quantitative meta-analysis after reading the eligible full texts with the inclusion and exclusion criteria.

Integration of the included studies on risk factors between patients with HAIs and patients without HAIs among TB hospitalized patients

Table 1 presents that in total, 11,922 TB hospitalized patients were included in the systematic review and meta-analysis. Of them, 1,133 were diagnosed as having HAIs, while the rest (110,789) were not with HAIs. All of the included studies were undertaken in tertiary general hospitals, which covered 10 regions in 9 provinces in China. Table 2 shows that the most frequent risk factors reported from the included studies were age (11/11), use of antibiotics (11/11), invasive procedure (9/11), and length of hospitalization (9/11).

Table 1

Characteristics of the studies included in the systematic and meta-analysis on risk factors for healthcare-associated infections among TB hospitalized patients in Chinese general hospitals from 2001 to 2020

Study ID	Author (Year)	Study design	Study setting	Region (Province)	Year begun and duration (years)	Number of participants	
						HAIs	Non-HAIs
Xiang et al. (2019) (22)	Retrospective cross-sectional	One tertiary hospital	Qiongzong	2015, 2	400	1,901	
Jiang et al. (2019) (21)	Retrospective cross-sectional	One tertiary hospital	Xining (Qinghai)	2016, 1.5	32	269	
3	Zhou et al. (2018) (19)	Retrospective cross-sectional	One tertiary hospital	Baoding (Hebei)	2015, 2.5	152	2,234
4	Huang et al. (2019) (20)	Retrospective cross-sectional	One tertiary hospital	Danzhou (Hainan)	2015, 1	78	78
5	Chen et al. (2018) (13)	Retrospective cross-sectional	One tertiary hospital	Wenling (Zhejiang)	2014, 3	28	653
6	Liu et al. (2015) (15)	Retrospective cross-sectional	One tertiary hospital	Zhuhai (Guangdong)	2005, 9	79	1,225
7	Dai et al. (2014) (14)	Retrospective cross-sectional	One tertiary hospital	Wenzhou (Zhejiang)	2012, 1	30	286
8	Gong & Wang (2013) (39)	Retrospective cross-sectional	One tertiary hospital	Binzhou (Shandong)	2006, 7	142	1,858
9	Zhang et al. (2012) (17)	Retrospective cross-sectional	One tertiary hospital	Weihui (Henan)	2008, 3.5	117	756
10	Zhong et al. (2010) (18)	Retrospective cross-sectional	One tertiary hospital	Foshan (Guangdong)	2007, 1	56	1,306
11	Zeng (2015) (16)	Retrospective cross-sectional	One tertiary hospital	Foshan (Guangdong)	2010, 4	19	223

Table 2

Frequency of the identified risk factors in the included studies on risk factors for healthcare-associated infections among TB 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	Total
Age	√	√	√	√	√	√	√	√	√	√	√	11
AIDS						√						1
Albumin (> 40 g/L vs. ≤ 40 g/L)		√										1
Complications					√					√	√	3
Course of disease (> 5 years vs. ≤ 5 years)		√										1
Diabetes mellitus			√			√						2
Gender	√	√	√	√	√	√	√		√			8
Invasive procedure		√	√	√	√		√	√	√	√	√	9
Length of hospitalization		√	√	√	√		√	√	√	√	√	9
Negativity of the sputum smear for acid fast staining	√	√										2
Secondary tuberculosis	√	√				√						3
Smoking			√		√							2
Tuberculosis retreatment	√											1
Underlying diseases	√	√	√	√				√	√			6
Use of antibiotics	√	√	√	√	√	√	√	√	√	√	√	11
Use of anti-tuberculous drug				√				√				2
Use of glucocorticoid	√											1

Quality assessment of the included studies

All of the 11 included studies were cross-sectional with a median score (10 points). All of the studies clearly defined the inclusion for the hospitalized patients, identified the confounding factors which had an impact on the occurrence of HAIs among TB hospitalized patients, and measured the outcomes in a valid and reliable way. However, none of the studies described the study setting with more details and only mentioned the hospital without any details. Also, variation of the HAIs prevalence existed among the included studies. It mainly showed that some studies did not describe how the HAIs prevalence among the TB hospitalized patients was calculated. The same situation was also applied to the standard criteria for the TB patients with HAIs and the strategy to deal with the confounding factors. (See Appendix 1)

Meta-analyses of all the potential risk factors

Table 3 shows that a total of 11 risk factors were included in the meta-analyses. The forest plot of each risk factor was presented in Supplementary Material: Appendix 2. Specific results were shown as follows.

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 TB hospitalized patients

Risk factors	Number of patients		Meta-analysis model	OR [95% CI]	$\hat{\tau}^2(P)$	I^2 (%)	P-value
	HAIs	Non-HAIs					
Age (≥ 65 years vs. < 65 years)	481	6,686	Random-effects	2.89 [2.01-4.15]	0.14 (0.006)	67	$< 0.01^*$
Complications	103	2,182	Fixed-effects	3.28 [2.10-5.13]	-	0	$< 0.01^*$
Diabetes mellitus	231	3,459	Fixed-effects	1.63 [1.22-2.19]	-	0	0.0009*
Gender	916	7,402	Fixed-effects	1.04 [0.90-1.21]	-	0	0.55
Invasive procedure	512	5,805	Random-effects	3.80 [2.25-6.42]	0.39 (< 0.01)	78	$< 0.01^*$
Length of hospitalization (> 15 days vs. ≤ 15 days)	317	4,971	Fixed-effects	2.09 [1.64-2.64]	-	44	$< 0.01^*$
Negativity of the acid-fast bacilli (AFB) smear and culture	432	2,170	Random-effects	1.23 [0.41-3.65]	0.54 (0.006)	87	0.71
Secondary tuberculosis	511	3,395	Random-effects	2.25 [1.48-3.42]	0.08 (0.10)	56	0.0001*
Smoking	180	2,887	Fixed-effects	1.40 [1.02-1.93]	-	0	0.04*
Underlying disease	779	5,238	Random-effects	2.66 [1.53-4.62]	0.33 (< 0.01)	87	0.0005*
Use of antibiotics	991	8,931	Fixed-effects	2.77 [2.35-3.27]	-	45	$< 0.01^*$

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

Age (> 60 years vs. ≤ 60 years): 7 studies (13–19) reported the age (> 60 years) of 279 with and 2,327 TB patients without HAIs. Random-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients who were over 60 years old than those who were younger than 60 years old (OR: 2.89, 95% CI: 2.01-4.15). There was a middle level of heterogeneity among the studies $\hat{\tau}^2=0.14$ ($P=0.006$), $I^2=67\%$).

Complications: 3 studies (13, 16, 18) reported the complications of 74 with and 943 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients with complications than those without complications (OR: 3.28, 95% CI: 2.10-5.13). The heterogeneity did not exist among the studies ($P=0.74$, $I^2=0\%$).

Diabetes mellitus: 2 studies (15, 19) reported the diabetes mellitus of 103 with and 1,177 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0009$) in patients with diabetes mellitus than those without diabetes mellitus (OR: 1.63, 95% CI: 1.22-2.19). The heterogeneity did not exist among the studies ($P=0.75$, $I^2=0\%$).

Gender: 8 studies (13–15, 17, 19–22) reported the gender (Male) of 539 with and 4,331 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was almost equal ($P=0.55$) between male patients and female patients (OR: 1.04, 95% CI: 0.90-1.21). The heterogeneity did not exist among the studies ($P=0.83$, $I^2=0\%$).

Invasive procedure: 8 studies (13, 14, 16–21) reported the invasive procedure of 225 with and 1,830 patients without HAIs. Random-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients who experienced invasive procedure than those who did not experience invasive procedure (OR: 3.80, 95% CI: 2.25-6.42). There was a high heterogeneity among the studies $\hat{\tau}^2=0.39$ ($P<0.01$), $I^2=78\%$).

Length of hospitalization (>15 days vs. ≤15 days): 6 studies (13, 14, 16, 18, 19, 21) reported the length of hospitalization (>15 days) of 200 with and 2,318 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients who had length of hospitalization over 15 days than those who had length of hospitalization less than 15 days (OR: 2.09, 95% CI: 1.64-2.64). The heterogeneity did not exist among the studies ($P=0.11$, $I^2=44\%$).

Negativity of the acid-fast bacilli (AFB) smear and culture: 2 studies (21, 22) reported the negativity of the acid-fast bacilli (AFB) smear and culture of 77 with and 310 patients without HAIs. Random-effects model showed that the prevalence of HAIs was higher ($P=0.71$) in patients who had negativity of the acid-fast bacilli (AFB) smear and culture than those who had positivity of the acid-fast bacilli (AFB) smear and culture (OR: 1.23, 95% CI: 0.41-3.65). There was a high heterogeneity among the studies $\hat{\tau}^2=0.54$ ($P=0.006$), $I^2=87\%$).

Secondary tuberculosis: 3 studies (15, 21, 22) reported the secondary tuberculosis of 145 with and 611 patients without HAIs. Random-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0001$) in patients who had secondary tuberculosis than those who did not have secondary tuberculosis (OR: 2.25, 95% CI: 1.48-3.42). There was a middle level of heterogeneity among the studies $\hat{\tau}^2=0.08$ ($P=0.10$), $I^2=56\%$).

Smoking: 2 studies (13, 19) reported the smoking of 111 with and 1,500 patients without HAIs. The fixed-effects model showed that the prevalence of HAIs was higher ($P=0.04$) in patients who smoked than those who did not smoke (OR: 1.40, 95% CI: 1.02-1.93). The heterogeneity did not exist among the studies ($P=0.59$, $I^2=0\%$).

Underlying disease: 5 studies (17, 19–22) reported the underlying disease of 322 with and 1,657 patients without HAIs. The random-effects model showed that the prevalence of HAIs was significantly higher ($P=0.0005$) in patients with underlying disease than those without underlying disease (OR: 2.66, 95% CI: 1.53-4.62). There was a high heterogeneity among the studies $\hat{\tau}^2=0.33$ ($P<0.01$), $I^2=87\%$).

Use of antibiotics: 10 studies (13–22) reported the use of antibiotics of 561 with and 4,306 patients without HAIs. Fixed-effects model showed that the prevalence of HAIs was significantly higher ($P<0.01$) in patients who used antibiotics than those who did not use antibiotics (OR: 2.77, 95% CI: 2.35-3.27). The heterogeneity did not exist among the studies ($P=0.06$, $I^2=45\%$).

Discussion

Our systematic review and meta-analysis first provided a comprehensive analysis of risk factors on HAIs among TB hospitalized patients in Chinese general hospitals. Our review found that older than 65 years, presence of complication, presence of diabetes mellitus, invasive procedure, longer than 15 days of hospitalization stay, secondary tuberculosis, smoking, presence of underlying disease, and use of antibiotics were the main risk factors which had a negative impact on HAIs among TB hospitalized patients in Chinese general hospitals. These findings provided evidence for the policy makers and hospital managers to make effective infection prevention and control measures to constrain the rising of HAIs.

Our systematic review found that TB hospitalized patients older than 65 years were more susceptible to HAIs than those younger than 65 years (OR: 2.89[2.01-4.15]). The number of aged population is rapidly rising in the globe. 1 in 6 people beyond the age of 65 years has been estimated in the world in 2050, which is much higher than 1 in 11 in 2019 (23). Elderly TB patients are recognized as the immune-compromised patients, who are at high risk of acquiring HAIs (24). This suggests that the elderly TB patients should be set as the priority and the surveillance of the elderly TB patients should be strengthened. Thus, it can result in decreasing the risk of getting HAIs among aged TB patients.

Presence of complication, diabetes mellitus, underlying disease, and secondary tuberculosis were found the main factors associated with high prevalence of healthcare-associated TB in our review. All of them mainly deteriorated the TB patients' immune systems. Consequently, TB patients were more susceptible to HAIs compared with those without above conditions. One study has confirmed that it was 2.5 times more likely to develop TB among patients with diabetes mellitus in developed countries (25). It was also found that diabetes mellitus was highly associated with multi-drug resistant TB (MDR-TB) in Asia (OR: 1.40[1.01-1.95]) in a systematic review and meta-analysis (26, 27). Presence of complication, diabetes mellitus, underlying disease, and secondary tuberculosis definitely affect the healthcare-associated TB patients' safety and prognosis, and put a challenge to the worldwide health system infection control strategy and clinical management, which further alert the global health development without any control measure.

The hazard of acquiring HAIs among TB hospitalized patients who had invasive procedure was higher than those without invasive procedure (3.80 [2.25-6.42]) in our review. Invasive procedure was actually not frequently reported that had a negative impact on healthcare-associated TB in existing research. However, invasive procedure, such as indwelling invasive device and surgery, indeed make the TB hospitalized patients predisposed to HAIs. A single-centre point-prevalence survey in an American hospital showed that 96.8% of hospitalized adult patients had at least one indwelling device (28). It indicated that invasive procedure was still widely adopted as a treatment among hospitalized patients, which put the patients into high exposure to HAIs.

Our review also found that smoking increased the risk of obtaining HAIs among TB hospitalized patients (OR: 1.40 [1.02-1.93]). Smoking, as a risk behaviour, can compromise the successful TB treatment due to poor adherence to the treatment among TB patients (29). Additionally, the majority of TB hospitalized patients belong to pulmonary TB. This suggests that pulmonary TB hospitalized patients are more likely to acquire healthcare-associated pneumonia. Therefore, TB patients who smoke, especially male patients, need to experience aspiration of sputum, fibrotic bronchoscope, and trachea cannula and so on due to the rising respiratory secretions in lung, thereby increasing the likelihood of HAIs. Personal intervention should be made for TB patients who smoke to stop the risky behaviour. Hence, the treatment of TB could be not more sophisticated and decrease the risk of getting HAIs.

TB hospitalized patients who stayed in hospital longer than 15 days were found to be more likely to obtain HAIs compared with those who had less than 15 days of hospitalization (OR: 2.09[1.64-2.64]) in our review. Prolonged hospitalization stay extends the exposure to HAIs among TB hospitalized patients, which is confirmed in some studies (30, 31). TB hospitalized patients who stay longer in hospital are more likely to have underlying disease or complications or invasive procedure and so on (32, 33). As previously mentioned, they promote the probability of the exposure to HAIs for TB hospitalized patients. It is necessary for the hospitals to shorten the hospitalization stay for the TB patients in order to lower the risk of HAIs exposure.

TB hospitalized patients were more risky to get HAIs if they used antibiotics during the treatment compared with their counterparts (OR: 2.77[2.35-3.27]). This finding is consistent with current studies (34). Use of anti-tuberculosis drug is the main way to treat TB for a long period (21). During the treatment, it is common to use antibiotics for TB patients concurrently. As a consequence, an increasing number of TB patients have been infected with multi-drug resistance. Goedele et al. also mentioned that successful TB treatment is compromised by drug resistance because of irrational use of antibiotics to treat TB (29). This indicates that prudent and high-quality antibiotics prescription and rational use of antibiotics are essential to constrain the overuse of antibiotics, thereby reduction in the occurrence of healthcare-associated TB. Moreover, antimicrobial stewardship program has been widely recommended as one way to achieve the rational use of antibiotics, including making straightforward and strict rational use of antibiotics guidelines and regulations, improving the clinical doctors' antibiotics prescription behaviour, and increasing the awareness of antimicrobial resistance among the public (35, 36).

The key to preventing the healthcare-associated TB after clearly investigating the risk factors associated with high occurrence of healthcare-associated TB is to implement effective infection prevention and control measures. Current literature has suggested that the exposure and transmission of healthcare-associated TB can be reduced with the implementation of infection prevention and control guidelines, which can increase the identification and isolation of the potential healthcare-associated TB patients (37). The United States, WHO, and other institutions have recommended effective infection prevention and control measures to decrease the occurrence of healthcare-associated TB, particularly a hierarchy of effective infection control measures, including administrative controls, environmental controls, and personal respiratory protection (38). Specially, the administrative controls are considered as the first and most important component to decrease the exposure to healthcare-associated TB. It is also required that more cost-effective infection prevention and control measures should be widely applied in routinely medical treatment and clinical management to healthcare-associated TB. Hence, the exposure and transmission of the healthcare-associated TB can be reduced and prevented.

Our systematic review and meta-analysis also has some limitations. First, the included studies were mostly published in Chinese journals since they were conducted in Chinese general hospitals. It encourages the researchers to publish their findings about risk factors for healthcare-associated TB in English journals to share the advanced knowledge. Second, we found the included studies were all conducted in a single hospital. It is required that multi-centre studies could be undertaken in future research to strengthen the current evidence base.

Conclusions

Older than 65 years, presence of complication, presence of diabetes mellitus, invasive procedure, longer than 15 days of hospitalization stay, secondary tuberculosis, smoking, presence of underlying disease, and use of antibiotics were the main risk factors which had a negative impact on HAIs among TB hospitalized patients in Chinese hospitals. These findings provided evidence for the policy makers and hospital managers to make effective infection prevention and control measures to constrain the rising of

HAIs.. It is also required that more cost-effective infection prevention and control measures should be widely applied in routinely medical treatment and clinical management to healthcare-associated TB. Hence, the exposure and transmission of the healthcare-associated TB can be reduced and prevented.

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.

Author contributions

The systematic review and meta-analysis was conducted under the charge of H.L. X.L. and N.R. searched the databases to find the relevant articles and assessed the quality of the included studies. X.L. undertaken the statistical analysis. X.L. and N.R. drafted and revised the manuscript. M.Z. adjusted the tables and figures. H.L. and Z.F. reviewed the manuscript, provided the feedbacks and did the proofreading.

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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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Figures

Figure 1

Flow chart of the searching relevant of published articles from the included 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; TB: Tuberculosis

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