



# The Application of Hazard Vulnerability Analysis in the Prevention and Control of COVID-19 in Medical Institutions

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## Abstract

**Background:** Coronavirus disease 2019 (COVID-19) has caused massive casualties, severe economic losses, and poses a threat to the world. This study's primary objective was to analyze the hospital's potential hazards of COVID-19 prevention and control. The second objective was to review the disaster plan and make recommendations to minimize the spread of COVID-19 in hospitals.

**Methods:** An expert group for the prevention and control of COVID-19 in the First People's Hospital of Longquanyi District, Chengdu, China was established. We adopted the hazard vulnerability analysis (HVA) to risk-stratify potential hazards and calculated relative risk values. We used the Delphi expert consultation method to propose and implement targeted improvement measures for the top five potential hazards. Then, the effects before and after the intervention were compared.

**Results:** The top five hazards were: insufficient Personal Protective Equipment (PPE) (25.68%), inadequate diagnosis ability of clinicians (22.55%), and inadequate management strategies of patients and caregivers (22.38%), lack of professional ability of pre-checking and triage staff (16.96%), lack of knowledge of COVID-19 of medical staff (15.59%). After taking targeted improvement measures, the average score of the hospital staff's COVID-19 knowledge test increased from 73.26 points to 90.44 points, the average test score of the outsourcing company employees increased from 68.55 to 89.75 points. The differences were statistically significant ( $P < 0.05$ ).

**Conclusion:** HVA can be used to systematically risk-stratify potential threats, measure the probability of those potential hazards, and develop various hospital prevention and control measures for COVID-19 epidemics.

**Keywords:** Hazard vulnerability analysis; COVID-19; Prevention and control

## Introduction

The Coronavirus disease 2019 (COVID-19) is the Class-B infectious disease managed as the Class-A infectious disease that first appeared in Wuhan in 2019. It spreads rapidly. There are no targeted drugs currently (1, 2), which has brought a massive

threat to human life (3). Thus, preventing and controlling the spread of COVID-19 is very important.

COVID-19 has atypical symptoms and a long incubation period. Humans are generally susceptible to COVID-19. As a densely populated place, hospitals have become a high-risk area for spreading



COVID-19 (4). Additionally, the spread of COVID-19 has occurred in many hospitals in China and worldwide. It is necessary to prevent and control the spread of COVID-19 in hospitals. However, the current hospital infection prevention and control management model cannot effectively control the spread of COVID-19. Therefore, this study used the hazard vulnerability analysis (HVA) by Kaiser Permanente (KP) to implement COVID-19 prevention and control vulnerability assessment. It was implemented in the hospital's key departments and critical links combined with the various prevention and control policies, guidelines, and literature of the country, provinces, and cities. The potential hazards in epidemic prevention and control were identified, and the corresponding hospital process was optimized in a targeted manner to minimize the occurrence of nosocomial cross-infection COVID-19.

## Materials & Methods

We adopted the First People's Hospital of Longquanyi District, Chengdu, as the research institute. Our hospital is one of the 17 COVID-19 designated treatment hospitals in Chengdu and the only hospital in Longquanyi District responsible for epidemic prevention and control of nearly 1.5 million people. The HVA of the hospital's COVID-19 prevention and control were implemented in our hospital.

### *Establish the Expert Group for COVID-19 HVA*

The Emergency Management Office took the lead in setting up an expert group for HVA of COVID-19. The group members were chiefs and backbones of the hospital infection and control department, medical quality control department, clinical departments, and logistics departments.

### *Develop a list of potential hazards.*

The expert group members searched and analyzed the articles, regulations, and documents of COVID-19 prevention and control published na-

tionally and internationally. On this basis, the hospital's procedures and the list of potential hazards for the spread of COVID-19 were sorted out. The list contains 14 first-level indicators and 37 second-level indicators.

### *Developing a potential hazards evaluation questionnaire*

According to the prepared list of potential hazards, an expert standardized evaluation questionnaire was developed based on the KP HVA tool. The HVA tool can generate a quantitative summary that includes hazard-specific relative risk scores (percentages) and graphs. It includes seven evaluation dimensions: probability, human impact, property impact, business impact, preparedness, internal response, and external response. Possibility and severity evaluation of loss is scored into four levels (0 = N/A, 1 = High, 2 = Moderate, 3 = Low or none). The evaluation of the completeness of prevention work (emergency preparation, internal response, and external support) is divided into four levels (0 = N/A, 1 = High, 2 = Moderate, 3 = Low or none) (5, 6).

### *Potential hazards evaluation and scoring*

Expert team members who analyze the hospital's vulnerabilities received comprehensive training. The training content was the use of the HVA tool and the requirements for the questionnaire. Then the standardized questionnaire was published through so jump, 'a platform providing functions equivalent to Amazon Mechanical Turk.' The expert group members scored the possibility and severity of various risk hazards in our hospital. A total of 49 questionnaires were returned, with a 100% response rate. Each potential hazard's relative risk values were calculated based on the probability and severity score and ranked high to low. The top priority was the main high-risk hazard that the hospital should pay attention to. Relative risk value (%) = (probability/3) × {(human impact + property impact+ business impact+ preparedness + internal response + external response) / 18}.

### *Targeted improvement measures*

The top five potential hazards were considered as

the priorities, which the hospital should input attention and resource. The team members used Delphi's method to propose targeted improvement measures to increase the hospital's epidemic prevention and control capabilities.

### Statistical Analysis

All data were statistically analyzed using SPSS (Chicago, IL, USA) 18.0 software. Quantitative data were described with  $\bar{x} \pm s$ ; the *t*-test was used for comparison between groups. A *P*-value of less than 0.05 is statistically significant.

## Results

### Investigation results of HVA for prevention and control of COVID-19

As shown in Table 1, the top five hazards of our hospital's COVID-19 prevention and control management were insufficient Personal Protective Equipment (PPE) (25.68%), the insufficient diagnostic ability of clinicians (22.55%), inadequate management of patients and caregivers (22.38%), insufficient professional capabilities of pre-examination and triage staff (16.96%), and insufficient of knowledge about COVID-19 prevention and control (15.59%).

**Table 1:** Investigation results of HVA for prevention and control of COVID-19

Event	PROBABILITY	SEVERITY			Preventive work completeness			Relative Threat*	Rank
		Human Impact	Property Impact	Business Impact	Preparedness	Internal Response	External Response		
Organization Building									
Imperfect management and prevention organization setting of COVID-19	0.41	2.43	2.20	2.31	1.08	1.04	1.10	7.68	34
Emergency plan									
COVID-19 epidemic prevention and control emergency plan is not perfect	0.39	2.39	2.16	2.24	1.08	1.04	1.12	7.21	36
Early detection									
Pre-examination and triage system is not perfect	0.45	2.51	2.14	2.29	1.06	1.04	1.12	8.45	28
Failure to set up pre-check triage points as required	0.43	2.43	2.08	2.24	1.02	1.04	1.12	7.89	33
Failure to strictly implement the three-level triage system	0.67	2.31	2.04	2.20	1.12	1.10	1.18	12.42	15
Failure to set up a fever clinic	0.45	2.45	2.10	2.35	1.04	1.06	1.12	8.42	29

The staff of the pre-checking and triage points have insufficient knowledge	0.94	2.14	1.86	2.20	1.16	1.20	1.18	16.96	4
Pre-examination triage points and fever clinic registration are not standardized	0.88	1.96	1.88	1.96	1.20	1.08	1.18	15.06	7
Early diagnosis									
The insufficient ability of COVID-19 diagnosis of clinicians	1.16	2.27	1.96	2.29	1.31	1.39	1.27	22.55	2
Early report									
The infectious disease reporting system is not revised in time	0.35	2.14	1.98	2.02	1.06	1.12	1.10	6.06	37
Medical staff do not know the standards and procedures for reporting COVID-19	0.63	2.10	2.02	2.06	1.14	1.16	1.18	11.33	20
COVID-19 reporting channels are blocked	0.47	2.04	1.88	1.98	1.06	1.10	1.16	8.02	31
No self-examination of COVID-19 reports	0.61	2.18	1.98	2.00	1.08	1.08	1.16	10.76	21
Early isolation									
No separate isolation wards	0.55	2.39	2.06	2.18	1.18	1.14	1.16	10.33	22
Inadequate rooms in isolation wards	0.69	2.24	1.96	2.18	1.18	1.16	1.20	12.77	14
No emergency isolation rooms in the general wards	0.71	2.12	1.96	2.12	1.24	1.20	1.20	13.04	13
Layout									
The layout of the isolation wards do not meet the requirements	0.53	2.29	2.02	2.12	1.06	1.12	1.14	9.59	25

The layout of the fever clinic does not meet the requirements	0.45	2.29	2.04	2.10	1.08	1.12	1.16	8.14	30
The emergency department layout does not meet the requirements	0.51	2.24	2.02	2.06	1.08	1.14	1.18	9.20	26
Unstandardized transfer routes from pre-check triage point to the fever clinics	0.49	2.14	1.88	2.04	1.08	1.08	1.14	8.50	27
In-hospital transfer flow channels for suspected or confirmed patients are not standardized	0.45	2.18	1.86	2.14	1.08	1.10	1.12	7.89	32
Cleaning and Disinfection									
No cleaning and disinfection system under an epidemic situation	0.41	2.27	2.04	2.06	1.06	1.12	1.14	7.33	35
Insufficient disinfection facilities and supplies	0.78	2.33	2.12	2.04	1.16	1.12	1.14	14.24	10
Failure to perform disinfection of air, surface, and ground as required	0.71	2.37	2.08	2.10	1.14	1.20	1.14	13.28	11
Personal protection equipment									
Insufficient PPE	1.27	2.41	2.27	2.27	1.37	1.31	1.35	25.68	1
Employees do not strictly carry out personal protection	0.71	2.53	2.29	2.29	1.33	1.31	1.29	14.49	9
No symptom monitoring mechanism of medical staff	0.82	2.29	2.04	2.08	1.16	1.12	1.16	14.90	8
Medical waste and sewage disposal									

Medical waste disposal and storage do not meet the requirements	0.63	2.20	2.18	2.12	1.12	1.10	1.16	11.60	17
Sewage treatment and monitoring do not meet standards Patient and caregivers management	0.57	2.14	2.04	2.10	1.06	1.06	1.12	10.09	24
Inadequate management of patients and caregivers	1.16	2.27	2.08	2.14	1.27	1.24	1.39	22.38	3
Staff Training									
Medical staff lacking infectious disease prevention and control knowledge	0.84	2.35	2.02	2.08	1.20	1.18	1.22	15.59	5
Supervision and inspection									
Failure to supervise personal protection, cleaning, and disinfection	0.65	2.08	1.98	2.00	1.10	1.12	1.10	11.35	19
Human resources									
Not enough emergency personnel	0.84	2.08	2.00	1.98	1.24	1.27	1.31	15.31	6
Lack of experts	0.76	2.06	1.94	1.94	1.20	1.10	1.22	13.24	12
Medical consortium mechanism									
No referral system	0.61	1.94	1.80	1.88	1.08	1.04	1.16	10.09	23
Imperfect sharing mechanism for information, materials, and experience	0.69	1.96	1.73	1.88	1.10	1.08	1.18	11.49	18

### *Comparison of COVID-19 knowledge of medical staff before and after implementing the targeted interventions*

Targeted training was taken in response to the high-risk hazards of clinicians' insufficient diagnostic ability, insufficient professional capabilities of pre-examination and triage staff, and insufficient knowledge about COVID-19 prevention and

control. The average score of the COVID-19 knowledge test for hospital employees increased from 73.26 points to 90.44 points after the targeted training. The average score of employees of the outsourcing company increased from 68.55 points to 89.75 points. The differences were statistically significant ( $P < 0.05$ ) (Table 2).

**Table 2:** Comparison of the average scores of hospital staff and outsourcing company staff on the COVID-19 knowledge test before and after implementing targeted training

<i>Personnel category</i>	<i>Number</i>	<i>Assessment average score (points)</i>		<i>t</i>	<i>P</i>
		Before interventions	After interventions		
Hospital staff	1094	73.26±11.24	90.44±3.25	22.73	0.016
Outsourcing company employees	360	68.55±7.65	89.75±4.22	26.45	0.021

### *Comparison of medical surgical mask consumption before and after the targeted interventions*

In response to the high-risk hazard of insufficient PPE, the average daily consumption of medical

surgical masks dropped from 1933 to 1136 after the targeted interventions, and the difference was statistically significant ( $P<0.05$ ) (Table 3).

**Table 3:** Comparison of consumption of medical surgical masks before and after the targeted interventions

<i>Time</i>	<i>Average daily consumption of surgical masks (pieces)</i>	<i>t</i>	<i>P</i>
Before targeted interventions	1933.83±986.21	3.092	0.004
After targeted interventions	1136.82±663.61		

## Discussion

The COVID-19 is the Class-B infectious disease managed as the Class-A infectious disease that first appeared in Wuhan, China, in 2019. It spread quickly throughout the country, posing a considerable threat to human life and health. Due to atypical symptoms, long incubation period, and general susceptibility to COVID-19, hospitals have become high-risk transmission areas. From Jan 1 to 28, 2020, among the 138 cases of COVID-19 confirmed in a hospital in Wuhan, China, the human-to-human transmission rate was as high as 41.3%. Hospital staff accounted for 29%, and inpatients accounted for 12.3%(7). It can be seen that the current nosocomial infection prevention and control management model cannot effectively control the spread of COVID-19 in the hospital. Therefore, it is very urgent to find the potential

hazards in the medical treatment process and nosocomial infection prevention and control measures of COVID-19. The corresponding preventive and response measures should also be taken.

The HVA tool is a mature tool used by institutions to evaluate specific hazards, intervene in advance, and eliminate hidden dangers in time(8). It is easy to access and widely used. During the assessment, HVA can be adjusted or appropriately modified for individual use. The HVA tool adopts a quantitative method to evaluate vulnerability, which ensures the objective evaluation results. The HVA tool has been widely used in hospital safety management, emergency management, hospital infection control management (9-12).

We adopted the HVA tool in optimizing COVID-19 prevention and control management. In this study, the HVA tool was used to analyze the vul-

nerability of key departments or links in the hospital of COVID-19 prevention and control. The results showed that under the COVID-19 epidemic situation, our hospital ranked top 5 potential hazards of nosocomial infection prevention and control. They were as follows: insufficient Personal Protective Equipment (PPE) (25.68%), insufficient diagnostic ability of clinicians (22.55%), inadequate management of patients and caregivers (22.38%), insufficient professional capabilities of pre-examination and triage staff (16.96%), and insufficient of knowledge about COVID-19 prevention and control (15.59%).

As an anti- COVID-19 epidemic weapon for medical staff, PPEs protect medical staff from infection. Facing the rapid epidemic of COVID-19, the problem of insufficient PPE has become more prominent. Therefore, the possibility and severity of the shortage of PPE in our hospital were both high. The relative risk value was 25.68%, which was the most urgent potential hazard to be solved. Our hospital initiated a special management project to solve this problem: ①Homemade protective masks. We checked the relevant literature and invented self-made non-woven masks. The filtration efficiency of bacteria and non-oily particles was no less than 99%, which met medical surgical masks' standards. ② Monitor inventory and allocate reasonably. The hospital infection management department monitored the daily inventory and the distribution of PPEs to determine whether the PPEs in key departments were sufficient and provided a basis for the hospital to deploy PPEs— ③Daily consumption monitoring. We monitored the daily consumption of each department and intervened in time if abnormal usage was observed. The results showed that the average daily consumption of medical surgical masks dropped from 1933 to 1,136 before and after the targeted management. The management and control of PPE were effective.

Early detection and early diagnosis are the basis for early isolation, diagnosis, and treatment. The rapid and frequent update of clinical guidelines of COVID-19 brings difficulties to medical staff in mastering prevention and treatment knowledge.

Therefore, the possibility of clinicians' insufficient professional ability and pre-examination triage point staff is high, which is similar to our investigation results. Our investigation showed that the relative risk value of medical staff's insufficient knowledge of prevention and treatment was as high as 15.59%. In response to this risk, our hospital established a training assessment team to apply the SMART principle to the training and managing the COVID-19 epidemic. The training course changed with different groups of people and different stages of the COVID-19 epidemic. Simultaneously, we conducted regular COVID-19 knowledge assessments and incorporated high error rates into the next exam questions. The results showed that the hospital staff's average score had increased from 73.26 to 90.44 points after targeted training. The average score of employees in outsourcing companies had increased from 68.55 points to 89.75 points. The COVID-19 knowledge of medical staff increased significantly.

We also strengthened health education, epidemiological history investigation, body temperature monitoring, and control of the number of accompanying persons, family members, and caregivers. Simultaneously, some management documents were formulated to manage the inpatient ward, outpatient department, and elevator use that apply to our hospital. These documents effectively managed patients and caregivers entering our hospital and reduced the hidden dangers of COVID-19 transmission.

## Conclusion

In this study, KP HVAs were successfully used to discover our hospital's potential hazards of COVID-19 epidemic prevention and control and formulate the optimal procedures and measures to minimize the risks of COVID-19 nosocomial infection. Moreover, the potential hazards faced by hospitals are not static. It will vary with the external environment and internal factors. Therefore, regular HVAs could be carried out in hospitals to assess the levels of hazards and enhance response



measures in time to improve the hospital's emergency management ability continuously.

### Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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### Conflict of interest

The authors declare that there is no conflict of interest.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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