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Nursing risk management of COVID-19 pneumonia isolation wards using HFMEA method

Xue Bai *

Jingzhou First People's Hospital, The First Affiliated Hospital of Yangtze University Jingzhou, Hubei, China, 43400.

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Abstract

To explore the application effect of Health care failure mode and effect analysis (HFMEA) in nursing risk management in COVID-19 pneumonia isolation ward, the risk management of nursing in isolation wards was evaluated by HFMEA method. According the six highest risk factor score, the improvement measures were formulated to intervene, and then nurse satisfaction was checked. After using HFMEA method, Risk Priority Number (RPN) of key indicators was lower than 18 points, the operating compliance rate was increased from 87 5% up to 98. 6%, and the satisfaction of nursing-related indicators was better than that of pre-implementation (P<0. 001). In a conclusion, applying HFMEA to the risk management of isolation wards in the early stage of the COVD-19 pneumonia epidemic can optimize the nursing management process, improve the quality of nursing care, reduce the safety risk and improve the job satisfaction of nurses.

Keywords: HFMEA; COVID-19; New Crown Pneumonia; Isolation Ward; Risk Management

1 Introduction

COVID-19 is now a pandemic since World Health Organization declared COVID-19 a public health emergency of international concern on January 30, 2020. Fever, cough, shortness of breath, fatigue, muscle pain, dyspnea, headache, hemoptysis, and diarrhea are the most common symptoms in patients infected with COVID-19. Some patients developed further fatal complications, including sepsis, septic shock, pulmonary edema, severe pneumonia, and acute respiratory distress syndrome [1,2]. The median incubation period of this disease is 4 days [3]. However, some infected patients report no symptoms and the asymptomatic ratio currently estimated at around 30.8% [4]. COVID-19 is transmitted primarily from person to person through respiratory droplets produced when an infected person coughs, sneezes or talks [5].

Nurses are the frontline healthcare professionals and play multiple important roles during this COVID-19 pandemic including implementing nosocomial infection prevention and surveillance; providing care to patients with COVID-19 who are in an acute or critical condition; providing the protection of patients with immune deficits or underlying diseases such as chronic obstructive pulmonary disease, chronic illnesses, and cancer; providing health education, screening services, and support for the general public and for individuals in high-risk categories. As COVID-19 is a newly identified disease, effective vaccines and treatments are still in development, nursing professionals face big challenges during COVID-19 pandemic. Improved the nursing risk management of COVID-19 pneumonia isolation wards is critical important during COVID-19 prevention and management.

* Corresponding author: Xue Bai
Jingzhou First People's Hospital, The First Affiliated Hospital of Yangtze University Jingzhou, Hubei, China, 43400.

125 COVID-19 pneumonia patients were treated and cured in closed management isolation ward of our hospital public health medical center between January 2020 and April 2020.

The quality management method used in this study was healthcare failure mode and effects analysis (HFMEA), which was revised from traditional failure mode and effects analysis (FMEA) and applied on healthcare system by the United States Department of Veterans Affairs [6-8].

In 2008, HFMEA was identified by the Technical Committee of the International Organization for Standardization (ISO) as a forward-looking risk analysis method for high-risk links. HFMEA has become a common tool in medical risk management in developed countries [9].

We applied HFMEA to the management of nursing risk in isolation wards in the early stages of the COVID-19 pneumonia epidemic for preventing loopholes in the management process, proposing reasonable suggestions and measures to eliminate the possibility of dangerous occurrence, and continuously improving quality.

2 Material and methods

2.1 Study period

Monitoring process of nursing quality was compared January 2020 (prior to implementation of HFMEA) and February and April 2020 (after implementation of HFMEA). HFMEA was performed between February 2020 and April 2020.

2.2 HFMEA methods

2.2.1 Team formation

A multidisciplinary team of nine members, including two instructors, three infection control professionals, three nurses, one information technician, was formed to conduct the assessment and develop improvement interventions.

2.2.2 Defining the process flow

Our team conducted monitoring via flowchart (Figure 1), and divided monitoring process into the wearing and taking off of personal protective equipment (PPE), lack of unified tools for body temperature monitoring, CT examination session of severe patients, air disinfection in potentially contaminated areas, in the collection of pharyngeal test paper without regulation on operation strength and test paper type, nonstandard writing of medical waste label, setting up buffer ward, distribution of patients (asymptomatic, mild, severe), the operation of high flow oxygen absorption machine lacks machine fault treatment and drying, nursing operation and communication psychological nursing and humanistic care, the timeliness of sampling and sample sending; the unified operation method of sampling, nutrition assessment and nutrition meal, intravenous rehydration.

2.2.3 Determining the failure mode and hazard analysis

In January 2020, we outlined all potential failure modes into four steps including (1) patients going to the outpatient clinic,(2) finding suspected or confirmed patients, (3) receiving isolation ward (including ward environment and layout, infection protection and management, vital signs monitoring and nursing, psychological assessment and support, specimen collection and management, condition observation and nursing, nutritional support and management, and patient outcome and Nursing), and (4) out of the hospital or death. At the same time, the potential effects and causes of each failure mode are discussed from the aspects of personnel, machinery, materials and methods. One week later, a second meeting was held to supplement the failure modes and determine the baseline investigation plan.

During the baseline survey period (between January and February 2020), we observed the occurrence of failure modes. In February 2020, the third meeting was held to grade and quantify the severity, occurrence and detection degree of failure modes. Grading criteria of failure mode severity (S) includes 10 levels (extremely serious, sub- extremely serious, very serious, relative severe, severe, medium, moderate, mild, very light, negative), and the corresponding scores are 10, 9, 8, 7, 6, 5, 4, 3, 2, 1. The scoring criteria of failure mode occurrence (O) analysis include 10 grades (extremely high, sub-extremely high, very high, high, frequent, accidental, infrequent, rare, extremely rare), and the corresponding scores are 10, 9, 8, 7, 6, 5, 4, 3, 2, 1. The scoring criteria of failure mode detection (D) include 10 levels, and the corresponding scores are 10, 9, 8, 7, 6, 5, 4, 3, 2, 1. The score of severity, occurrence and detection of failure mode is calculated according to the average score reported by each team member. The risk priority number (RPN) of a single failure mode is calculated by severity times occurrence times detection degree [10]. The greater the RPN score, the higher the degree

of the failure mode (Table 1). The principle of decision tree is shown in Figure 2. Based on the decision tree algorithm, we finally decided to take countermeasures for the following six failure modes (Table 1 in bold): (1) identification of the wearing and taking off links of personal protective equipment (PPE),(2) air disinfection in potentially contaminated areas, (3) CT examination session of severe patients, (4) in the collection of pharyngeal test paper without regulation on operation strength and test paper type,(5) the operation of high flow oxygen absorption machine lacks machine fault treatment and drying, (6) nonstandard writing of medical waste label.

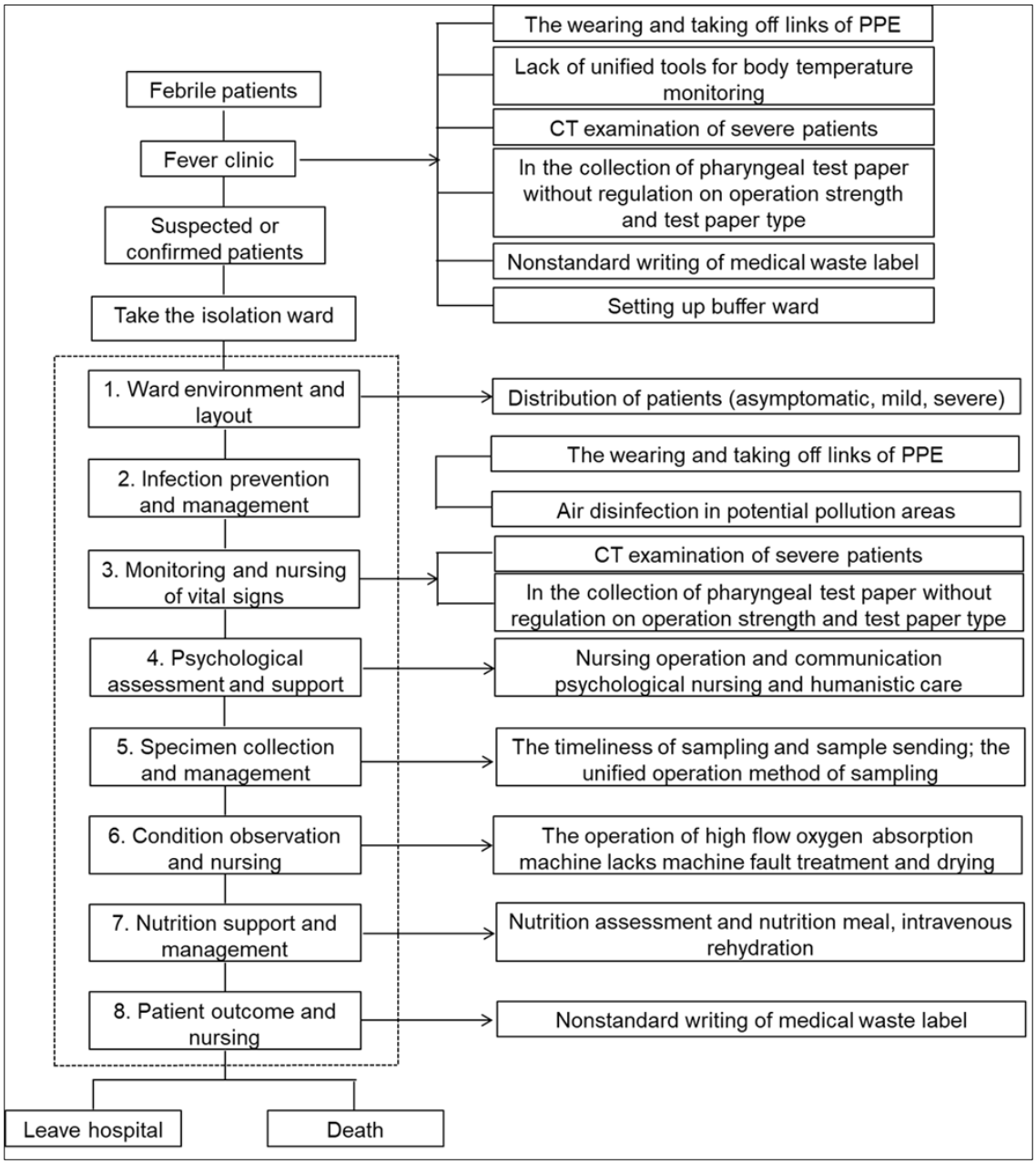

Figure 1 Flow chart for nursing risk management of COVID-19

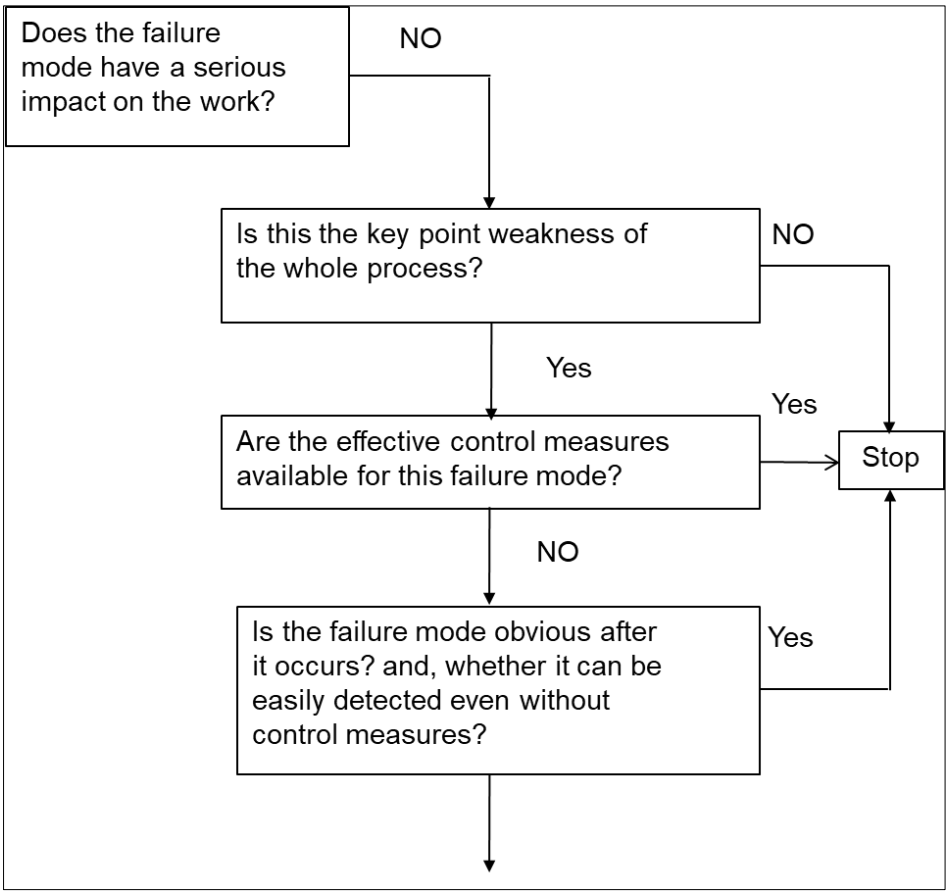

Figure 2 The decision tree algorithm

2.2.4 Detection of potential failure causes and definition of actions

Table 1 Potential failure-mode risk analysis and decision

Process step	Failure mode	Cause of failure	Risk analysis				Action or Stop#
			S	O	D	RPN	
Patients going to the outpatient clinic	The wearing and taking off links of PPE	Insufficient SOP and policies	8	5	5	200	Action
		Lack of training	8	1	5	40	Action
	Lack of unified tools for body temperature monitoring	Insufficient SOP and policies	8	5	3	120	Action
		Non-uniform sampling and report forms	5	5	5	125	Action
		Task was not assigned to individual	6	5	5	150	Action
	CT examination of severe patients	Insufficient SOP and policies	8	4	5	160	Action
		Lack of training	5	3	5	75	Action
		Task was not assigned to individual	4	2	5	40	Action
	In the collection of pharyngeal test paper without regulation on operation strength and test paper type	Non-uniform sampling and report forms	6	3	5	90	Action
		Insufficient SOP and policies	8	5	5	200	Action
		Lack of training	6	3	5	90	Action

	Nonstandard writing of medical waste label	Insufficient SOP and policies	8	5	5	200	Action
		Non-uniform sampling and report forms	5	2	6	60	Action
		Lack of training	6	2	5	60	Action
	Setting up buffer ward	Insufficient SOP and policies	8	2	5	80	Stop
		Task was not assigned to individual	6	1	5	30	Stop
Finding suspected or confirmed patients	Distribution of patients (asymptomatic, mild, severe)	Task was not assigned to individual	8	2	6	96	Stop
Receiving isolation ward	The wearing and taking off links of PPE	Insufficient SOP and policies	8	5	5	200	Action
	Air disinfection in potential pollution areas	Insufficient SOP and policies	8	4	5	160	Action
		Task was not assigned to individual	6	2	5	60	Action
	CT examination of severe patients	Insufficient SOP and policies	8	4	5	160	Action
		Lack of training	5	3	5	75	Action
		Task was not assigned to individual	4	2	5	40	Action
	In the collection of pharyngeal test paper without regulation on operation strength and test paper type	Non-uniform sampling and report forms	6	3	5	90	Action
		Insufficient SOP and policies	8	5	5	200	Action
		Lack of training	6	3	5	90	Action
	Nursing operation and communication	Task was not assigned to individual	6	2	5	60	Stop
	psychological nursing and humanistic care	Task was not assigned to individual	8	4	5	160	Action
	The timeliness of sampling and sample sending; the unified operation method of sampling	Non-uniform sampling and report forms	8	2	5	80	Action
		Insufficient SOP and policies	8	1	5	40	Action
		Lack of training	8	1	5	40	Action
	The operation of high flow oxygen absorption machine lacks machine fault treatment and drying	lacks machine fault treatment and drying	8	5	5	200	Action
	Nutrition assessment and nutrition meal, intravenous rehydration	Task was not assigned to individual	6	2	5	60	Stop
	Nonstandard writing of medical waste label	Non-uniform sampling and report forms	8	5	5	200	Action
		Insufficient SOP and policies	5	2	6	60	Action
Out of the hospital or death	Follow up and nucleic acid detection of patients who leaved hospital or death	Insufficient SOP and policies	5	2	6	60	Stop
		Non-uniform sampling and report forms	5	3	4	60	Stop

		Task was not assigned to individual	6	2	5	60	Stop

Note: S, Severity. O, Occurrence. D, Detection. RPN, Risk Priority Number. # determined by decision tree. SOP, standard operation procedures.

We summarized the possible causes of the 6 identified failure modes (table 1) and used system diagrams to identify the potential root causes (Figure 3). They were insufficient standard operation procedures (SOP) and policies; task was not assigned to individual, lacks machine fault treatment and drying, non-uniform sampling and report forms. In view of the above primary causes, we formulated multiple countermeasures, and evaluated their feasibility, economy and effectiveness. The scoring method is shown in table 2. The score of each member is the sum of feasibility, economy and efficiency, with the highest score of 15 points and the lowest of 3 points. There are ten team members with a full score of 150 points, the minimum score of 30 points for each countermeasure. According to the two-eight rule, more than 120 points were selected. Finally, 14 countermeasures were adopted (Table 3). It is integrated into six improvement schemes: (1) Revising and improving the wearing and taking off links of PPE; (2) fixed the monitoring task to each department and improved the CT examination of severe patients; (3) standardizing the Stuart throat swab collection operation, unify the test paper type, training the operation; (4) Revising and improving the specification of high flow oxygen inhalation machine operation and final treatment; (5) improving the treatment process of patients with emotional stress disorder; (6) standardizing and improving the medical waste disposal process.

Table 2 The scoring method for countermeasure

Feasibility		**Economy**		**Efficiency**	
level	**Score**	**level**	**Score**	**level**	**Score**
Highly feasible	5	low economic input	5	fully achieves the expected goal	5
Feasible	3	moderate economic input	3	partly achieves the expected goal	3
Infeasible	1	high economic input	1	unable to achieve the expected goal	1

Note: Each member's score was the sum of feasibility, economy and efficiency, with the highest score of 15 points and lowest score of 3 points. There were ten team members with a full score of 150 points and lowest score of 30 points for each countermeasure.

Table 3 Scoring table for countermeasures

Process step	**Cause**	**Countermeasure**	**Evaluation**					**Planned implementation time**	**Scheme number**
			feasibility	**economy**	**efficiency**	**Total**	**selected**		
the wearing and taking off links of PPE	Insufficient SOP and policies	Revision SOP and policies for monitoring of disinfection or nursing quality	50	50	50	150	yes	Jan. 2020	1
	Lack of training	Regular study of SOP and policies	40	40	50	130	yes	Jan.-Apr. 2020	3
		Face to face personal training and on-site demonstration operation	41	29	50	120	yes	Jan.-Apr. 2020	3
		Establishment of Wechat's Group for easy communication	50	50	45	145	yes	Jan.-Apr. 2020	3
		Focus on training staff in departments whose monitoring	50	50	50	150	yes	Jan.-Apr. 2020	3

		process is not up to standard							
	Task was not assigned to individual	Fixed Task to individual	50	50	46	146	yes	Jan.-Apr. 2020	2
		Department of infection monitoring tasks control in charge of overall	15	50	48	113	no	/	/
In the collection of pharyngeal test paper	Non-uniform sampling and report forms	Using lab information systems as clinical samples do, stopping the handwriting form.	40	50	50	140	yes	Jan.-Apr. 2020	5
		Unified an Excel sampling form for improvement period.	46	40	42	128	yes	Jan.-Apr. 2020	1
		Development an information management system, stopping the Excel form.	45	50	50	145	yes	Feb.-Apr. 2020	5
	Insufficient SOP and policies	Revision SOP and policies for monitoring of disinfection or Nursing quality	50	50	50	150	yes	Jan.-Apr. 2020	1
	Lack of training	Regular study of SOP and policies	40	39	50	129	yes	Jan.-Apr. 2020	3
		Regular on-site simulation operation	39	32	35	106	no	/	/
		Face to face personal training and on-site demonstration operation	41	30	50	121	yes	Jan.-Apr. 2020	3
		Establishment of Wechat's Group for easy communication	50	50	45	145	yes	Jan.-Apr. 2020	3
		Focus on training staff in departments whose monitoring process is not up to standard	50	50	50	150	yes	Jan.-Apr. 2020	3
Operation and final treatment	lacks machine fault	Implementation a management system for	43	50	50	143	yes	Jan.-Apr. 2020	5

of high flow oxygen absorber	treatment and drying	machine fault treatment and drying							
Treatment of patients with emotional stress disorder	Task was not assigned to individual	Fixed Task to individual	50	50	43	143	yes	Jan.-Apr. 2020	2
		Department of infection monitoring tasks control in charge of overall	15	48	45	108	no	/	/
Medical waste disposal	Non-uniform sampling and report forms	Using lab information systems as clinical samples do, stopping the handwriting form.	40	50	50	140	yes	Jan.-Apr. 2020	5
		Unified an Excel sampling form for improvement period.	46	40	42	128	yes	Jan.-Apr. 2020	1
		Development an information management system, stopping the Excel form.	45	50	50	145	yes	Feb.-Apr. 2020	5
	Insufficient SOP and policies	Revision SOP and policies for monitoring of disinfection or nursing quality	50	50	50	150	yes	Jan.-Apr. 2020	1

Note: PPE, personal protective equipment. SOP, standard operation procedures. 1 represents the revision SOP for monitoring of disinfection quality; 2, fixing monitoring task in each department; 3, training; 4, purchasing necessary devices and materials; 5, implementation an information management system for monitoring of disinfection quality.

2.2.5 Assessment

The qualified rate of operation process was selected as the index to evaluate the effect of HFMEA. Pass rate (%) = correct action / required action × 100%. Only when each step is carried out correctly can the whole process be considered correctly. As long as one step goes wrong, the whole process will go wrong. Team members examined the implementation of 14 monitoring tasks that required rigorous operation. Data before and after HFMEA were collected. On-site check form is shown in Table 4.

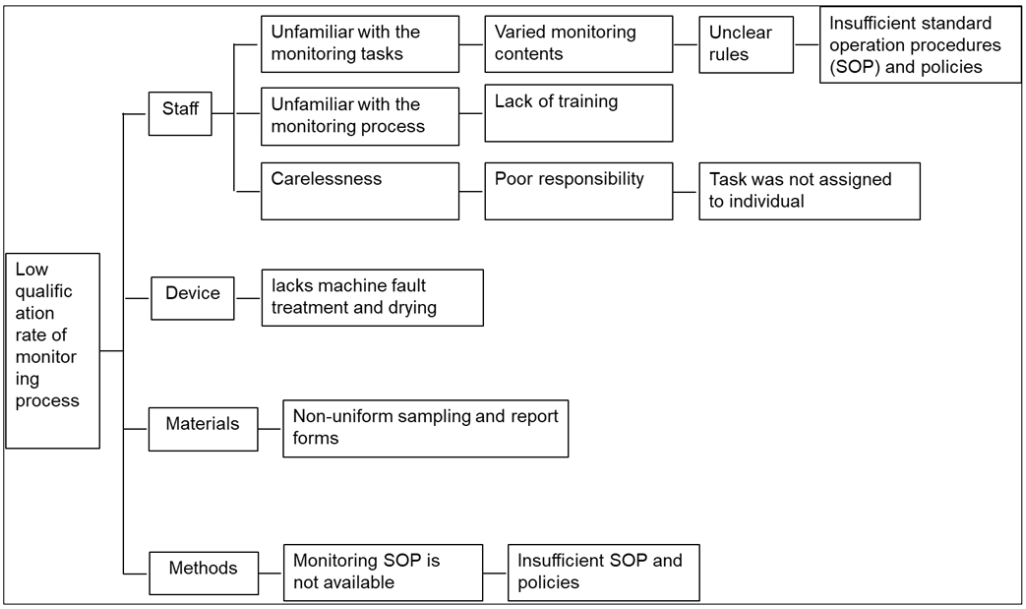

Figure 3 System diagram of possible root causes of failure modes

Table 4 Checklist for the monitoring process of the disinfection effect

Monitoring department	
Monitoring items	□Staff □Device □Materials □Methods
step	Implementation
Fever clinic	Proper using PPE:□yes □no; Proper for body temperature detection:□yes □no; Proper in the collection of pharyngeal test paper:□yes □no; Proper writing of medical waste label:□yes □no; Proper setting up buffer ward:□yes □no;
Suspected or confirmed patients	Proper CT examination of severe patients:□yes □no;
Ward environment and layout	Proper distribution of patients (asymptomatic, mild, severe):□yes □no;
Infection prevention and management	Proper using PPE:□yes □no; Air disinfection in potential pollution areas:□yes □no;
Monitoring and nursing of vital signs	Proper CT examination of severe patients:□yes □no; Proper in the collection of pharyngeal test paper:□yes □no;
Psychological assessment and support	Proper Nursing operation and communication:□yes □no; Proper psychological nursing and humanistic care:□yes □no;
Specimen collection and management	Proper operation method of sampling:□yes □no; The timeliness of sampling and sample sending:□yes □no;
Condition observation and nursing	The operation of high flow oxygen absorption machine has machine fault treatment and drying:□yes □no;
Nutrition support and management	Nutrition assessment and nutrition meal, intravenous rehydration:□yes □no;
Patient outcome and nursing	Proper writing of medical waste label:□yes □no;
Overall process	The overall monitoring process was implemented correctly: □yes □no

Note: Only all the ten steps were marked "yes" can the overall process be considered as "yes". Otherwise, the overall process was marked "no"

2.2.6 Estimation of sample size

According to a pilot survey before implementation of HFMEA, the qualification rates of the wearing and taking off links of personal protective equipment (PPE), air disinfection in potentially contaminated areas, CT examination session of severe patients, in the collection of pharyngeal test paper without regulation on operation strength and test paper type, The operation of high flow oxygen absorption machine lacks machine fault treatment and drying, nonstandard writing of medical waste label and overall monitoring process were 35%, 60%, 18%, 85%, 85%, 32%, and 11%, respectively. After implementation of HFMEA, the improvement goal was 90% of qualification rate for each of the above seven steps, while 80% for overall monitoring process. With the presetting test level (α= 0.05) and test power (1-β= 0.9), the estimated sample size was calculated by the following equation, $n = 2(\mu_\alpha+\mu_\beta)^2 2p(1-p)/\delta^2$, where $\delta = p_e - p_c$ and $p = (p_e+p_c)/2$; p_e , p_c referred to the qualification rate before and after HFMEA, respectively. The calculation results demonstrated that at least 14 monitoring processes would be examined for each of the two periods. Monitoring was conducted in 4 months with totally 185 monitoring processes. In order to completely master the quality of monitoring during the study periods, we decided to enroll all 185 monitoring processes.

2.3 Data analysis

SPSS 22.0 software (IBM, Armonk, NY, USA) was used to perform statistical analysis. Chi-square test was used to compare the rates. Pearson's chi-square test was applied if the theoretical frequency (T) < 5 but ≥ 1. Fisher's exact test was applied if T < 1. P < 0.05 was considered statistically significant.

3 Results

3.1 The improvement for Risk Priority Number (RPN) of failure mode

After application of varied action plans between January 2020 and April 2020, the Risk Priority Number (RPN) of each failure mode decreased significantly (Table 5).

Table 5 Risk Priority Number (RPN) of failure modes before and after HFMEA

Process step	Potential failure mode	Root causes	Countermeasure	Before implementation				After implementation			
				S	O	D	RPN	S	O	D	RPN
The wearing and taking off links of PPE	(1) The disinfection measures of buffer room are not strict;	(1) Insufficient SOP and policies.	(1) Revision SOP and policies for monitoring of disinfection or Nursing quality	8	5	6	240	3	2	3	18
	(2) Inconvenient handling of goggles	(2) Lack of training.	(2) Training								
		(3) Task was not assigned to individual									
CT examination session of severe patients	(1) Patients with severe illness were not evaluated for going out for examination	(1) Insufficient SOP and policies.	(1) Revision SOP and policies for monitoring of disinfection or Nursing quality.	7	6	5	210	4	2	2	16
	(2) The route is not strictly blocked	(2) Lack of training.	(2) Training.								
		(3) Task was not assigned to individual.	(3) Fixed Task to individual.								
In the collection of	(1) The process is only for one sample tube;	(1) Non-uniform sampling and report forms.	(1) Revision SOP and policies for monitoring	6	5	6	180	3	2	2	12

pharyngeal test paper			of disinfection or Nursing quality.								
	(2) without regulation on operation strength and test paper type	(2) Insufficient SOP and policies.	(2) Training.								
		(3) Lack of training.	(3) Using lab information systems as clinical samples do, stopping the handwriting form.								
Operation and final treatment of high flow oxygen absorber	(1) Lack of machine troubleshooting process	(1) Lacks machine fault treatment and drying.	(1) Implementation a management system for machine fault treatment and drying.	6	5	5	150	3	1	2	6
	(2) without drying link in the final treatment										
Treatment of patients with emotional stress disorder	(1) Neglect of the patient's psychology;	(1) Task was not assigned to individual	(1) Fixed Task to individual	5	5	6	150	3	1	2	6
	(2) Less communication between the patient and the outside world, anxiety and tension										
Medical waste disposal	(1) The process of novel coronavirus pneumonia identification is complicated;	(1) Non-uniform sampling and report forms	(1) Using lab information systems as clinical samples do, stopping the handwriting form.	5	6	5	150	3	1	1	3
	(2) The temporary storage of medical waste is not standardized.	(2) Insufficient SOP and policies	(2) Revision SOP and policies for monitoring of disinfection or Nursing quality								
			(3) Development an information management system, stopping the Excel forms.								

Note: S, Severity. O, Occurrence. D, Detection. RPN, Risk Priority Number

3.2 The improvement for each monitoring step

After HFMEA, the qualification rate of each step improved from 54.59%, 57.30%; 57.84%, and 58.92% to 98.92%, 99.46%, 99.46%, and 100.00%, respectively ($P < 0.001$ for all comparisons). The qualification rate of the overall monitoring process improved from 52.97% to 98.38% ($P < 0.001$, Table 6).

Table 6 Qualification rate of monitoring process before and after HFMEA

Step	Before implementation			After implementation			P
	Correct actions	Required actions	Qualification rate (%)	Correct actions	Required actions	Qualification rate (%)	
Patients going to the outpatient clinic	101	185	54.59	183	185	98.92	＜0.001
Finding suspected or confirmed patients	106	185	57.30	184	185	99.46	＜0.001
Receiving isolation ward	107	185	57.84	184	185	99.46	＜0.001
Out of the hospital or death	109	185	58.92	185	185	100.00	＜0.001
Overall process	98	185	52.97	182	185	98.38	＜0.001

3.3 The improvement for operation compliance rate

For all four items (Staff, Device, Materials, and Methods) implemented by the clinical department, the qualification rate was 52.97% for overall monitoring items before HFMEA, and the qualification rate was increased to 100% for all monitoring items ($P < 0.001$, Table 7) after HFMEA.

Table 7 Qualification rate of steps implemented by clinical department for different monitoring items before and after HFMEA

Items	Before implementation			After implementation			P
	Correct actions	Required actions	Qualification rate (%)	Correct actions	Required actions	Qualification rate (%)	
Staff	31	64	48.44	64	64	100.00	<0.001
Device	18	35	51.43	35	35	100.00	<0.001
Materials	27	47	57.45	47	47	100.00	<0.001
Methods	22	39	56.41	39	39	100.00	<0.001
Total	98	185	52.97	185	185	100.00	<0.001

3.4 The improvement for nurses' satisfaction with nursing quality in isolation ward

Nurses' satisfaction for the six steps (the wearing and taking off links of PPE, CT examination session of severe patients, the collection of pharyngeal test paper, operation and final treatment of high flow oxygen absorber, and treatment of patients with emotional stress disorder, medical waste disposal) were analyzed. After HFMEA, the qualification rate of each step improved from 70%, 72.5%, 67.5%, 70.0%, 75.0%, and 80.0% to 95.0%, 97.5%, 97.5%, 95.0%, 97.5%, and 95.5%, respectively ($P < 0.001$ for all comparisons). The qualification rate of the overall monitoring process improved from 16.5% to 78.7% ($P < 0.05$ for most comparisons except for medical waste disposal, Table 8). After HFMEA, the nurses' compliance rate was increased from 87.5% to 98.6% ($P < 0.001$, Table 9).

Table 8 Comparison of nurses' satisfaction with nursing quality related indicators in isolation ward before and after implementation

Items	Before implementation of improvement measures(n=40)			After implementation of improvement measures(n=40)			P
	satisfied	commonly	dissatisfied	satisfied	commonly	dissatisfied	
The wearing and taking off links of PPE	28(70.0)	9(22.5)	3(7.5)	38(95.0)	2(5.0)	0(0.0)	0.011
CT examination session of severe patients	29(72.5)	7(17.5)	4(10.0)	39(97.5)	1(2.5)	0(0.0)	0.007
The collection of pharyngeal test paper	27(67.5)	8(20.0)	5(12.5)	39(97.5)	1(2.5)	0(0.0)	0.002
Operation and final treatment of high flow oxygen absorber	28(70.0)	8(20.0)	4(10)	38(95.0)	2(5.0)	0(0.0)	0.010
Treatment of patients with emotional stress disorder	30(75.0)	7(17.5)	3(7.5)	39(97.5)	1(2.5)	0(0.0)	0.013
Medical waste disposal	32(80.0)	4(10.0)	4(10.0)	38(95.5)	2(5.0)	0(0.0)	0.075

Notes: PPE, personal protective equipment.

Table 9 Comparison of nurses' compliance rate before and after implementation

Time	Total number of operations	Times of reaching the standard	Compliance rate (%)
Before implementation	560	490	87.5
After implementation	560	552	98.6
$\chi 2$			52.971
P			<0.001

4 Discussion

It is difficult to prevent and control new crown pneumonia for its non- typical symptoms, long incubation period, and multiple routes of infection including respiratory droplets, secretions, excreta, and contact. The risk control of nursing workflow using HFMEA is effective in reducing the incidence of nosocomial infection.

After the implementation of the improvement measures, the RPN value of all processes dropped significantly from 150~240 to 3~18 points (Table 5). This indicates that effective management can be conducted based on a prospective assessment of the risk factors of failure mode management in the nursing process of the new COVID-19 pneumonia pandemic using the HFMEA method, so as to maximize the safety of medical staff in the process of medical service, to avoid the loss caused by the risk factors of nosocomial infection.

The application of HFMEA promoted the improvement of nursing key operation skills. During the COVID-19 pneumonia pandemic, the accuracy of the key operation of nursing staff is crucial to ensure the quality of nursing care and reduce

the incidence of infection of medical staff. In the new environment, strong infection requires the staff to strengthen the training of operation skills.

After HFMEA implementation, the key operation processes were improved. The results showed that the qualification rate in key operation increased significantly (Table 6) and the compliance rate of staff operation examination increased from 48.44% to100% ($P < 0.01$) (Table 7).

The application of HFMEA is also adequate to improve nurses' satisfaction with safety management and control. For nurses in isolation wards, the work intensity is high, and the physical consumption is increased. The improvement of process can improve nurses' work efficiency and the satisfaction of process.

After the improvement of the key process of nursing operation, the satisfaction of nurses was greatly improved ($P < 0.05$ for most comparisons except for medical waste disposal) (Table 8). Because some nurses who have never been engaged in infection related specialist work temporarily joined the pandemic prevention and control team, there are doubts about the relevant work system, work procedures, and quality standards. The implementation of HFMEA method can manage the key operation process from a scientific point of view, ensure the safety of nursing work, eliminate the doubts of staff, and improve the quality of nursing in isolation ward and nurse satisfaction.

This work was intended as an example of the use of HFMEA, and it is by no means fully comprehensive. The failure modes identified by our team members may not fully reflect all the potential failures in nursing risk monitoring [11]. However, the work on reconstructing the approach of systematic process quality control offers healthcare facilities a new protocol that can be used to implement quality improvements for nursing quality monitoring processes through multidisciplinary cooperation and implementation of comprehensive measures. HFMEA not only helped to improve the qualification rate of nursing quality monitoring but also reinforced team cohesiveness and the culture of continuous quality improvement and safety.

In COVID-19 pneumonia, the early infection prevention and control management risk points were analyzed by using HFMEA theory, and the potential causes were identified. The improvement measures were utilized to improve the awareness and the level of protection of nurses. This approach ensures the safety of healthcare professionals, and enhances the overall quality of nursing teams. Moreover, it ensures that the ward work can be completed safely and efficiently. For the isolation of COVID-19 pneumonia in the initial stage, our method improves the ability of prevention, control management, and emergency reserve.

5 Conclusion

For the isolation of COVID-19 pneumonia in the initial stage, the improved nursing management using HFMEA method can effectively reduce the incidence of nosocomial infection, improve the quality of nursing care, improve the job satisfaction of nurses and enhances the overall quality of nursing teams. We provides an effective method to improve the ability of prevention, control management, and emergency reserve in the early stage of the COVID-19 pneumonia epidemic.

Compliance with ethical standards

Authors' contributions

Xue Bai conceived and coordinated the study, designed the study, performed the study, analyzed the result and wrote the manuscript.

Disclosure of conflict of interest

No conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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