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Research on Vaccine Distribution and Reserve Based on Service Level during Major Infectious Disease Epidemics

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Abstract: *Purpose:* To explore the effect of vaccine distribution and reserve based on service level under major infectious disease epidemics. *Methods:* The study included 200 subjects, who were divided into 2 groups according to computer randomization method, with 100 subjects in the control group and the experimental group. The experimental group implements a vaccine allocation strategy based on service level, and the control group adopts conventional allocation. The implementation effect of the allocation strategy of the two groups is evaluated. *Results:* The experimental group had a higher complete vaccination rate (92.00% vs. 85.00%), and the comparison of vaccination coverage between the two groups was $P > 0.05$. The experimental group had a higher vaccine utilization rate (96.33% vs. 85.67%), and the comparison was $P < 0.05$. The average vaccination time in the experimental group was shorter, and the vaccination timeliness score was higher, with a comparison $P < 0.05$. The incidence of adverse reactions in the 2 groups (8.00% vs. 6.00%), comparison $P > 0.05$. The satisfaction score of the experimental group was higher, comparison $P < 0.05$. *Conclusion:* For major infectious disease epidemics, implementing a vaccine distribution strategy based on service levels in prevention and control can effectively improve the efficiency of vaccination and vaccine utilization, ensure the timeliness and safety of vaccination, and thereby improve public satisfaction.

Keywords: Vaccine distribution; Reserve strategy; Service level; Infectious disease epidemic; Public health

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1. Introduction

Infectious disease epidemics have become a persistent problem that seriously affects global public health security. The epidemic spreads quickly and affects a wide range, which has brought severe tests to the epidemic prevention work of various countries. Vaccination is the most direct and effective intervention in epidemic prevention and control. However, in actual work, it has been found that the actual prevention and control effect of the vaccine not only depends on the immune efficacy of the vaccine itself, but is also closely related to the rationality of the distribution strategy and reserve plan [1]. At present, the focus of vaccine prevention and control is mainly focused on breakthroughs in vaccine research and development technology and production processes. There is less research on how to scientifically distribute vaccines. As a result, when facing an emergency epidemic, vaccine supply is often difficult to meet all needs immediately. Therefore, it is of great significance to establish a scientific distribution mechanism to ensure that limited resources can maximize their effectiveness [2]. The service level-based distribution model provides an objective basis for vaccine allocation by quantitatively assessing the epidemic risks and resource needs in different regions, thereby improving the overall effectiveness of epidemic prevention and control [3]. In this regard, this study analyzes the implementation effect of the service level-based vaccine distribution strategy to effectively respond to public health emergencies, which is summarized as follows:

2. Materials and methods

2.1. General information

The study included 200 subjects, who were divided into 2 groups according to the computer randomization method, with 100 subjects each in the control group and the experimental group. The experimental group included 56 males and 44 females, aged 22–65 years old, with an average age of 43.28 ± 12.35 years old; the control group included 52 males and 48 females, aged 21–67 years old, with an average age of 44.16 ± 13.02 years old. Comparison of baseline data between the 2 groups $P > 0.05$.

Inclusion criteria: (1) Age 18–70 years old; (2) Meet the vaccination indications; (3) Voluntarily participate in the study.

Exclusion criteria: (1) Immune system diseases; (2) Plans to leave the region during the study; (3) History of severe vaccine adverse reactions.

2.2. Method

The control group adopts the traditional vaccine distribution method, and allocates uniformly based on the number of applications submitted by each vaccination point, ensuring that the number of vaccines obtained by each vaccination unit is basically consistent with the number of applications. During the distribution process, the vaccine supply to all vaccination sites is handled according to the same standards. Each vaccination site independently determines the vaccination progress based on its own work capacity and the situation of the vaccination recipients. The vaccination order is flexibly controlled by the vaccination site staff based on the actual visit situation, and the principle of first-come, first-served is usually adopted.

The trial group adopts a vaccine allocation strategy based on service levels.

(1) The assessment needs to fully consider key factors such as the number of confirmed cases in the region, population density, and medical resource carrying capacity. The assessment process is completed by professionals from the Centers for Disease Control and Prevention, and is dynamically updated once a week to ensure that the risk level classification can reflect the latest development trend of the epidemic promptly. The risk level is divided into three levels: high, medium, and low, and each level corresponds to a different resource allocation plan, providing a scientific basis for subsequent accurate allocation.

(2) For areas with different risk levels, fully consider the priorities of epidemic prevention and control, formulate differentiated service level standards, and clarify the time requirements, resource allocation proportions and priorities for the entire process from vaccine distribution to completion of vaccination. High-risk areas receive the highest priority to ensure that limited resources are tilted towards areas most in need; medium-risk areas adopt the principle of moderate priority and are allocated on the premise of ensuring the needs of high-risk areas; low-risk areas serve as the final protection targets to ensure that basic epidemic prevention needs are met.

(3) High-risk areas implement the strictest service standards. Starting from the arrival of the vaccine at the distribution center, vaccination of the target population must be completed within 24 hours, including special vehicle delivery, priority scheduling, and the establishment of temporary vaccination points. At the same time, sufficient medical personnel will be deployed, vaccination service hours will be extended, and 24-hour uninterrupted vaccination will be carried out when necessary. At the same time, vaccine reserves in high-risk areas should be maintained at 150% of regular demand to ensure that vaccination needs can still be met in emergencies.

(4) The service standards in medium-risk areas are relatively loose, but clear time limits are also set. The entire process from vaccine distribution to completion of vaccination is controlled within 48 hours. Vaccine distribution adopts a

regular shuttle bus model, which departs at a fixed time every day. The number of vaccination points is reasonably set according to the population size, and the opening hours are extended to 12 hours; the vaccine reserve is maintained at 120% of regular demand, which not only ensures sufficient supply but also avoids waste of resources. When the epidemic escalates to high risk, it can immediately switch to high-risk regional service standards.

(5) Basic service standards are implemented in low-risk areas, and the time limit for completing vaccination is relaxed to 72 hours. Vaccine distribution is included in the regular logistics system, with fixed delivery twice a week. Vaccination points mainly rely on existing medical institutions, and no additional temporary vaccination points will be added. Service hours remain normal. time; the vaccine reserve is maintained at 100% of regular demand, and an inter-regional adjustment mechanism is established. Under the premise of ensuring the basic needs of the region, some vaccines can be deployed to support other high-risk areas. When the epidemic situation fluctuates, the service standard upgrade process can be initiated within 12 hours.

(6) In actual implementation, specific responsible persons should be set up for each link to ensure that all measures are implemented in place, the implementation effects are regularly evaluated, and the risk level classification standards and service level requirements are dynamically adjusted based on the evaluation results to form a continuously optimized closed-loop management.

2.3. Observation indicators

(1) Vaccination coverage rate: actual number of people vaccinated/number of people to be vaccinated × 100%

(2) Timeliness of vaccination: the time from the arrival of the vaccine to the completion of vaccination; vaccination timeliness score: ≤ 24 h = 3 points, 25–48 h = 2 points, 49–72 h = 1 point, > 72 h = 0 points.

(3) Vaccine utilization rate: actual doses used/distributed doses × 100%.

(4) Incidence rate of adverse reactions: number of cases of adverse reactions/total number of vaccinations × 100%.

(5) Satisfaction rating: A 10-point scale is used and is subjectively evaluated by the subjects.

2.4. Statistical methods

The SPSS26.0 software was used to process the data involved in the study. Measurement data were expressed as "(mean ± SD)" and tested by "t"; count data were expressed as "[*n*/(%)]" and tested by "χ^2". $P < 0.05$ indicated that the difference was significant.

3. Results

3.1. Comparison of vaccination coverage and vaccine utilization rates

The complete vaccination rate in the experimental group was higher (92.00% vs 85.00%), the comparison of vaccination coverage between the two groups was $P > 0.05$; the vaccine utilization rate in the experimental group was higher (96.33% vs 85.67%), the comparison was $P < 0.05$. (**Table 1**).

Table 1. Comparison of vaccination coverage and vaccine utilization rates between the two groups [*n* (%)]

Group	Vaccination coverage (n=100)			Vaccine utilization		
	Fully vaccinated	Partial vaccination	Not vaccinated	Assign dose	Dosage	Utilization
Experimental group	92 (92.00)	6 (6.00)	2 (2.00)	1200	1156	96.33
Control group	85 (85.00)	10 (10.00)	5 (5.00)	1200	1028	85.67
χ^2	2.563	83.354				
P	0.278	0.000				

3.2. Timeliness of vaccination

The average time of vaccination in the experimental group was shorter, and the vaccination timeliness score was higher, with a comparison $P < 0.05$ (**Table 2**).

Table 2. Comparison of vaccination timeliness between two groups (mean ± SD)

Group	n	Average time (h)	Timeliness score (points)
Experimental group	100	26.34 ± 8.72	2.38 ± 0.72
Control group	100	38.15 ± 12.46	1.65 ± 0.83
t	-	7.766	6.644
P	-	0.000	0.000

3.3. Incidence of adverse reactions

The incidence of adverse reactions in the 2 groups (8.00% vs 6.00%), comparison $P > 0.05$ (**Table 3**).

Table 3. Comparison of the incidence of adverse reactions between the two groups [*n* (%)]

Group	n	Local reaction	Systemic reaction	Incidence rate (%)
Experimental group	100	5 (5.00)	3 (3.00)	8 (8.00)
Control group	100	4 (4.00)	2 (2.00)	6 (6.00)
χ^2	——	——	——	0.307
P	——	——	——	0.579

3.4. Satisfaction score

The satisfaction score of the experimental group was higher, comparison $P < 0.05$ (**Table 4**).

Table 4. Comparison of satisfaction scores between the two groups (mean ± SD, points)

Group	n	Convenience of vaccination	Service attitude	Process efficiency	Overall satisfaction
Experimental group	100	8.72 ± 1.25	8.56 ± 1.32	8.91 ± 1.18	8.63 ± 1.27
Control group	100	7.35 ± 1.48	7.82 ± 1.54	6.97 ± 1.63	7.24 ± 1.52
t	-	7.072	3.648	9.641	7.018
P	-	0.000	0.000	0.000	0.000

4. Discussions

Vaccines are one of the most effective intervention methods for preventing and controlling infectious diseases. The scientific nature of their distribution and reserve strategies is directly related to the effectiveness of epidemic prevention and control. Currently, in response to sudden epidemics, although the conventional vaccine distribution method is reasonable to a certain extent, it has exposed many shortcomings [4]. Conventional allocation is based on the number of applications and adopts the principle of unified allocation. Although it is easy to operate, it ignores the differences in epidemic severity and resource demand in different regions, which can easily lead to insufficient vaccine supply in high-risk areas and idle resources in low-risk areas. This not only reduces the overall prevention and control efficiency, but also fails to reflect the principle of fairness in public health resource allocation. In actual operation, routine allocation often lags behind the development of the epidemic due to the lack of a dynamic adjustment mechanism. Although the way in which vaccination sites independently determine the order of vaccination is flexible, it is difficult to ensure that high-risk groups receive priority vaccination rights [5].

The core of the vaccine distribution strategy based on service level is to break the average distribution of the conventional distribution model. Through risk level assessment, comprehensively consider key indicators such as the number of confirmed cases, population density, and hospital carrying capacity, and establish a scientific, flexible, and operable hierarchical response mechanism to achieve accurate allocation of vaccine resources and ensure that limited vaccines can be tilted to areas most in need [6].

The results of this study showed that the experimental group had a higher complete vaccination rate (92.00% vs. 85.00%), and the comparison of vaccination coverage between the two groups was $P > 0.05$. It shows that implementing a targeted allocation strategy can better meet the actual vaccination needs [6]. The vaccine utilization rate in the experimental group was higher (96.33% vs 85.67%), with a comparison $P < 0.05$. It fully demonstrates that implementing a hierarchical distribution strategy can significantly reduce resource waste and maximize the value of each dose of vaccine [7].

The results of the study showed that the average vaccination time of the experimental group was shorter and the vaccination timeliness score was higher, with a comparison $P < 0.05$. It fully reflects that hierarchical service standards have a positive impact on process optimization. For high-risk areas, strict requirements to complete vaccination within 24 hours, combined with measures such as special vehicle delivery and temporary vaccination site settings, can effectively compress the time window from vaccine arrival to completion of vaccination. Although the time limit is relatively loose in medium and low-risk areas, clear time nodes and accountability systems can still ensure the orderly advancement of vaccination work. Through differentiated management, emergency needs in key areas are ensured, thereby improving overall efficiency [8].

The results of the study showed: the incidence rate of adverse reactions in the 2 groups (8.00% vs 6.00%), comparison $P > 0.05$. The incidence rates of adverse reactions in the two groups were within a reasonable range and there was no significant difference, indicating that the implementation of the service level-oriented allocation strategy was not at the expense of safety, and that the use of hierarchical allocation would not increase vaccination pressure and thus affect operating specifications [9].

The research results showed that the experimental group had a higher satisfaction score, comparison $P < 0.05$. It has been confirmed that the implementation of a distribution strategy based on service levels can effectively solve the resource misallocation problem in conventional distribution, effectively improve the timeliness and safety of vaccination, thereby meeting the expectations of the public and improving satisfaction with vaccination [8].

5. Conclusion

In summary, for major infectious disease epidemics, implementing a vaccine distribution strategy based on service levels in prevention and control can effectively improve the efficiency of vaccination and vaccine utilization, ensure the timeliness and safety of vaccination, and thereby improve public satisfaction.

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Disclosure statement

The author declares no conflict of interest.

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