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Performances of Integrated Care Organization in Fighting Post-COVID-19 Public Health Crisis: Introduction and Evaluation of the Luohu Model

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Abstract: The Luohu integrated care organization reorganized its care delivery model in less than one week to fight against medical chaos right after quarantine, outperforming other integrated care systems in China; therefore, this study aims to summarize the practice of Luohu model and evaluate its performance. Specifically, we summarized Luohu integrated care organization in reshaping its care delivery model between Dec 9th, 2022 and Jan 19th, 2023 to combat potential medical chaos, and evaluated the performance of Luohu in avoiding infections and medical expenditure savings as compared to normal practices. The study was conducted within the Luohu integrated care organization, recognized as a pioneer in China's integrated care reform, with data collected from a total of 45 Community Health Centers (CHCs) and key healthcare facilities within the district. The study population was not limited by sex or ethnic group. The selection criteria for the healthcare facilities were based on their integration into the Luohu integrated care organization, and there was no exclusion criteria for facilities based on size or type, ensuring a comprehensive assessment of the integrated care system. As primary outcomes, the study assessed changes in visit structure, infections averted, cost savings, and satisfaction levels among both doctors and patients. The results showed that the Luohu model primarily focuses on online medication and drug distribution, training for temporary general practitioners, and establishment of community-based fever clinics. This model averted an average of 490 daily infections per 100,000 people served by the community health center, while also saving $10,736.32. Patient satisfaction with the rapid response services was at 100% (n=209). Additionally, primary care physicians reported a significant increase in workload, necessitating physical and psychological support (n=34). In conclusion, Luohu's success in restoring medical order lies in its integrated management in the usual time and its ability to flexibly restructure under environmental changes, demonstrating that integrated delivery systems have greater potential against emergent medical crises.

1. Introduction

Since 2016, China has responded actively to the World Health Organization's (WHO) call for patient-centered integrated care[1,2]. By the end of 2023, China had established 18,000 integrated care organizations, with over 10,000 in urban areas[3,4] and aimed to achieve comprehensive coverage of closely integrated care organizations nationwide by 2027[5-7]. Luohu integrated care delivery system was established at a comparatively early stage in 2015, which was one of the first districts[8]. Luohu has reorganized its service delivery model, shifting from emphasizing functions to focusing on an outcome-oriented approach centered around health effects, and constructed a community-based and prevention-oriented integrated care system[9]. This involves centralizing the management and allocation of community equipment, medications, and personnel[10]. This highly integrated model improves service continuity and coordination, enabling rapid identification and response to demands. As a result, it has gained recognition from the global community[11-14].

On December 9th, 2022, China lifted stringent isolation measures following the three-year implementation of the "*silent*" policy[15, 16]. Faced with the predictable treatment chaos, China urged the integrated care organizations in urban and rural to react quickly and implement measures to combat these challenges, such as providing nucleic acid testing equipment and personnel at community compounds to facilitate nearby testing[17-19]. However, due to the urgent timeline, integrated care organizations were unable to adequately plan manpower, finances, medications, and treatment models. A significant surge in cases still occurred between Dec 2022 and Jan 2023[20-22]. The study found that self-reported infection rates peaked between Dec 19th and 21st, 2022, and as of Feb 7th, 2023, with 82.4% of the Chinese population having been infected[23]. However, research conducted in Shenzhen found that 76.8% of respondents reported experiencing COVID-19 symptoms,a rate that is lower than the national average[24]. Especially, in Luohu district, Luohu integrated care organization established 36 emergent departments for fever in 36 CHCs within a week, and effectively addressing the challenges faced by safeguarding the health of approximately 1.018 million people. Luohu's approach has been lauded and acknowledged by the central government, which has come to recognize that integrated care organizations can not only provide usual care but also effectively respond to public health crises. Currently, there is no evidence summarizing or validating Luohu's practices or evaluating their outcomes.

This study employs empirical evidence-based evaluations to analyze the response strategies implemented by the Luohu integrated care organization in the post-COVID-19 era. It examines the potential of integrated care organizations in addressing the post-COVID-19 public health crisis, offering insights for enhancing disease diagnosis, treatment protocols, and both routine and emergency management within Chinese medical consortia during future public health crises. Moreover, these findings may serve as a reference for other countries facing similar global public health challenges.

2. Methods

2.1. Study setting

Luohu District, located in Shenzhen City, Guangdong Province, is a pioneer in development and a vital component of Shenzhen's Central Business District. It is home to China's largest land port, witnessing over 100 million entries and exits annually[25]. By the end of 2022, the district's permanent population stood at 1.018 million[26], governed by 10 sub-districts, 81 community service stations, and 109 residents' committees. The seventh national population census revealed a significant demographic mobility, with 792,671 individuals having a disconnect between their household registration and actual residence, including 156,001 within the municipal area and 636,670 classified

as a floating population[27].

In the ongoing medical reform, Shenzhen has selected Luohu District as a pilot to establish a closely integrated medical consortium. This consortium integrates the district's key healthcare facilities, including the people's hospital, traditional Chinese medicine hospital, maternal and child health care hospital, chronic disease prevention and treatment hospital, geriatric disease specialty hospital, and all community health service centers. The Luohu integrated care organization was established to coordinate 45 community health centers, rationally allocate medical resources, and uniformly manage medical resources across the district. The reform has led to an increase in the proportion of basic diagnostic and treatment volume in community health centers from 21.01% in 2014 to 49.00% in 2019. Additionally, information technology has been leveraged to facilitate a two-way referral system, enabling shared medical records, priority registration, examination, treatment, and hospitalization. In 2018, the consortium managed a total of 20,800 patients referred upwards and 24,900 patients referred downwards[28], establishing an orderly three-tiered medical visit order. Figure 1 presents the organizational structure of the Luohu integrated care organization.

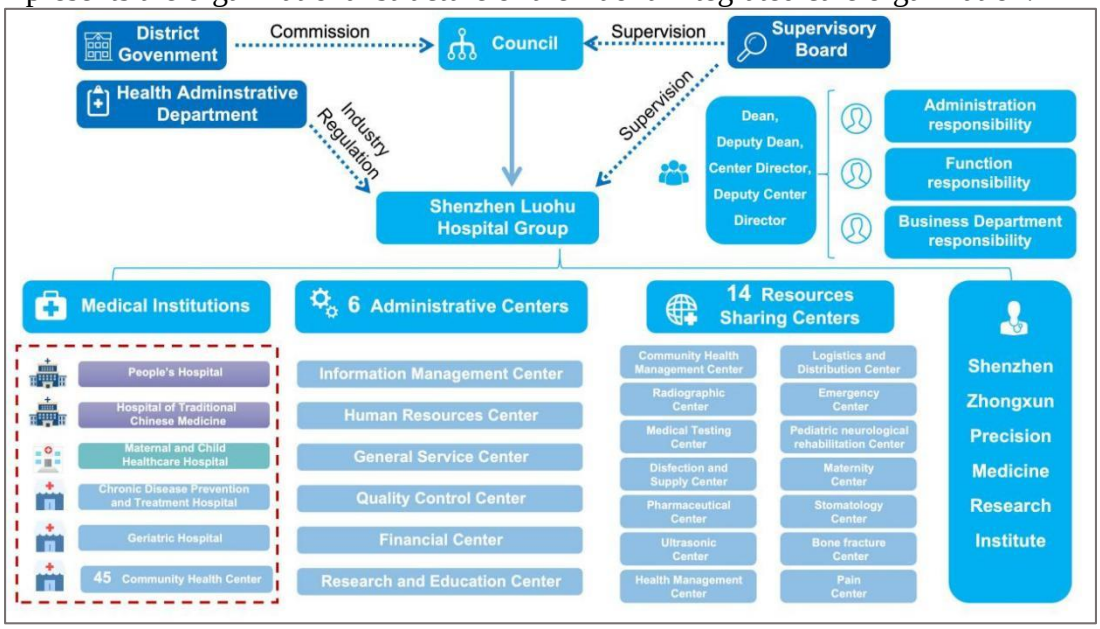

Figure 1: Organizational structure of the Luohu integrated care organization

2.2. Qualitative data collection

In partnership with the Luohu integrated care organization, our research team undertook a 72-day investigative study across two periods: Dec 7th, 2022, to Jan 20th, 2023, and Jul 9th, 2023, to Aug 4th, 2023. The study was conducted at the Luohu District People's Hospital and encompassed seven CHCs. Utilizing a mixed-methods approach, we engaged in on-site observations, conducted site visits, and facilitated interviews. The interviews, which included discussions with the director of the interview office and the head of human resource management, spanned 3 hours and 14 minutes. Additionally, conversations with the officials from Shunjiang Street Community Health and Nanhu Street Community Health lasted 2 hours and 48 minutes. Simultaneously, we procured primary official documentation, comprising internal documentation from the Luohu integrated organization's HIS, records procured from the Luohu integrated organization's office throughout the pandemic and policy documents related to the "medical reform" initiatives in Luohu integrated organization. These interviews and documents provided the substantive basis for our thorough analysis of the strategic actions implemented by Luohu, which are summarized in the initial segment of the results section.

Change in the visit structure: This indicator is defined by the ratio of primary-level and online patient visits at hospital and offline patient visits. The calculation involves comparing the number of primary care and online consultations with those of hospital and in-person visits to assess shifts in patient access patterns.

Infection avoided and cost saving: This metric quantifies the estimated number of infections prevented and the associated cost savings. It is calculated using a model that considers the reduction in close contacts, potential virus spread, and healthcare service utilization through minimized outdoor visits and infection transmission prevention.

Formula:

Daily number of avoided infections at the CHC = Average daily number of patient visits × Positive rate of fever patients × Average daily number of contacts × ((1-mask wearing rate) + mask wearing rate × (1-mask effectiveness)^2) × Average probability of contacting infected individuals × (1-average COVID-19 infection rate in China) × (Average travel time for visits to the CHC / Average travel time for visits to the hospital)

Daily number of avoided infections at the internet hospital = Average daily number of patient visits × Positive rate of fever patients × Average daily number of contacts × ((1-mask wearing rate) + mask wearing rate × (1-mask effectiveness)^2) × Average probability of contacting infected individuals × (1-average COVID-19 infection rate in China)

Average daily avoidance cost (US Dollar) = Average daily number of avoided infections × Average cost per patient visit

Doctors' Satisfaction: This indicator measures the level of satisfaction among doctors. It is calculated based on responses collected through quantitative methods, including self-designed paper-based and electronic questionnaires that assess various aspects of job satisfaction.

Patients' Satisfaction: Similar to doctors' satisfaction, this indicator is gauged through quantitative methods. Patient satisfaction is measured using self-designed paper-based and electronic questionnaires that capture patient experiences and perceptions of healthcare services received.

2.3. Quantitative data collection and analysis

During the period spanning December 2022 to January 2023, in conjunction with these institutions, our data collection encompassed the administration of satisfaction surveys targeting general practitioners within community health clinics and residents partaking in community-based services. We also amassed data pertaining to online medical consultations and primary care visits, thereby enriching our understanding of the healthcare delivery mechanisms and their reception among the populace during this critical juncture. This study involved human participants, and ethical considerations were carefully evaluated. Informed consent was obtained from all survey participants prior to data collection, ensuring that they were fully aware of the study's objectives, procedures, and potential risks. The study's reliance on self-reported data from surveys, which did not involve the use of primary data in other analyses.

2.3.1. Infection avoided and cost saving

The parameters utilized in the model primarily stemmed from publicly available literature involving Chinese populations as the study subjects. The average cost per patient visit was derived from Luohu integrated organization's average visit cost, and the average COVID-19 infection rate was sourced from statistical data provided by the WHO.

Table 1: A Parameters input.

Parameter	Assumption Description	Baseline	Range	Source
Average daily number of individuals contacted	Assumes the population has uniform contact	16.70	15.03-18.37	Huang Y et al (2020)
Rate of appropriate mask-wearing	/	16.05	14.45-17.66	Zhang L et al (2021)
Mask effectiveness, %	Assumes infection risks correlate directly with travel duration	50.00	45.00-55.00	Ueki et al (2020)
The average probability of contacting infected individuals, %	/	6.40	57.60-70.40	Thron C et al (2021)
Average cost per patient visit, US Dollar	Assumes no infection risk associated with online consultations in internet hospitals, where patients receiving prescriptions can mitigate health risks while reducing expenses	21.92	0-403.85	Statistics
Average travel time for visits to the hospital, min	/	45.00	30.00-60.00	Xiong J. et al.(2012)
Average travel time for visits to the CHC, min	Assumes a 15-minute duration for visits to the CHC	15.00	5.00-30.00	Hypothesis
Consultation time ratio (hospital/CHC)	/	3.00	1.00-12.00	Calculated
Average daily number of visits to fever clinics in CHCs	/	2005.00	588.00-5047.00	Statistics
Positive rate of febrile patients, %	Assumes 70% of patients with fever visiting the clinic test positive	70.00	50.00-90.00	Hypothesis
Average daily patient volume in Internet respiratory departments	/	96.36	8-528	Statistics
Average COVID-19 infection rate in China, %	/	6.85	6.16-7.53	WHO (2023)

Sensitivity analysis

We conducted a deterministic sensitivity analysis to assess the uncertainty surrounding the baseline analysis results. This analysis utilized a one-factor-at-a-time approach, where each parameter was varied individually while holding others constant. This method enabled us to gauge the impact of each model parameter on the outcomes. We established the value ranges for each variable at a 95% confidence interval. In instances where data were unavailable, we selected a ±10% range for each parameter. The findings of this analysis are depicted using a tornado diagram.

2.3.2. Satisfaction survey

To evaluate the satisfaction levels of both doctors and patients, we employed quantitative methods, including self-designed paper-based and electronic questionnaires. Specifically, doctors' satisfaction was assessed through a comprehensive survey of the sample population, and patient satisfaction was gauged using a random sampling technique, ensuring a diverse and representative sample. Informed consent was obtained from all survey participants prior to data collection. Given the nature of the data, which did not involve primary data in other analyses and ethical considerations were not applicable, statistical analysis was conducted using Excel. Logistic regression analysis of patient satisfaction was performed using SPSS 26.0.

3. Results

3.1. Fighting public health crisis

Between Dec 9th and Dec 18th, 2022, Luohu integrated organization launched 36 fever clinics in CHCs. To bolster the medical workforce, the organization deployed 34 doctors from 15 departments to these CHC fever clinics.

To minimize outpatient travel: implementing internet hospital services. To reduce going out and leaving the community, Luohu People's Hospital initiated Internet Hospital services in February 2020, seamlessly integrating them into its operational framework. Initially excluding fever consultations, online fever consultations were introduced on Dec 9th, 2022, accessible through the Luohu Internet Hospital's mini-program or WeChat official account. This service was tailored for asymptomatic positive cases and residents exhibiting "Top Ten Symptoms" such as fever, dry cough, and sore throat. For offline patients across diverse locales (residential/office), the hospital facilitated registration and payment processing and provided dedicated examination and inspection facilities. Diagnostic outcomes were promptly transmitted to the Internet hospital system, enabling patients to access online physician assessments and interpretations, thereby curtailing wait times, mitigating the risk of cross-infections, and alleviating congestion in larger medical facilities. This proactive measure led to enhanced diagnostic throughput and heightened patient satisfaction. The integrated administrative structure in Luohu established a comprehensive pharmaceutical inventory, encompassing antipyretic and respiratory medications, to address deficiencies in the drug supply. The hospital efficiently managed emergency drug requisitions and allocation, ensuring prompt doorstep delivery through courier services like SF Express. Through collaboration with pharmaceutical suppliers, the hospital streamlined the distribution of medications requisite for CHCs. Collective endeavors by stakeholders facilitated expedited drug delivery to patients within a 24-hour window, thus affording timely access to essential pharmaceuticals.

To alleviate clinic overload: deploying temporary general practitioners. During peak periods at the fever clinic, specialized doctors from various departments provided assistance to both the central hospital and CHCs. Through centralized training and ongoing self-learning initiatives, selected staff members were proactively prepared to diagnose and treat fever patients. The Luohu healthcare system utilized the General Medicine Department as a central hub, mobilizing general practitioners and nurses from CHCs to offer support during high-demand periods. In addition to the critical care ward, three wards specialized in general medicine were established to accommodate patients with varying degrees of illness. Hospitalized patients were promptly directed to the appropriate specialized wards by the central facility, with personnel from diverse departments available for deployment as required.

To prevent cross-infection: establishing a network of fever clinics. Across 10 streets, a network of 36 fever clinics was established. The coordination between fever clinics at the central hospital and those at CHCs effectively mitigated the risk of cross-infection stemming from patients traveling long distances[29]. On Dec 25th, 2022, the central hospital repurposed its surgical ward into a critical care unit, reallocating both medical personnel and equipment, including ventilators and monitors, to bolster the capacity of critical care beds. The integrated Luohu organization strategically prioritized the admission of critically ill patients, resulting in an 84.89% utilization rate of critical care beds by January 13th, 2023.

To protect the vulnerable elderly: providing door-to-door care. The healthcare system in Luohu introduced a comprehensive, door-to-door elderly care service package targeted at individuals aged 65 and older. This package encompassed various components such as the provision of home hospital beds meeting established standards, relevant services, complimentary quarterly home visits, referral services, and assistance in scheduling appointments with medical specialists. Additionally, it afforded

priority access to medical services, hospital admission, and hospice care. Tailored to individual health conditions, the package included referrals to municipal or provincial hospitals and consultations with medical experts. Integration of smart home care platforms facilitated appointment-based online care, including complimentary home bathing for disabled elderly individuals. Specialized "Green Channels" were established for specific groups, implementing personalized strategies and enabling online medication ordering to address gaps in elderly care provision. Figure 2 illustrates the aforementioned measures within the Luohu healthcare system.

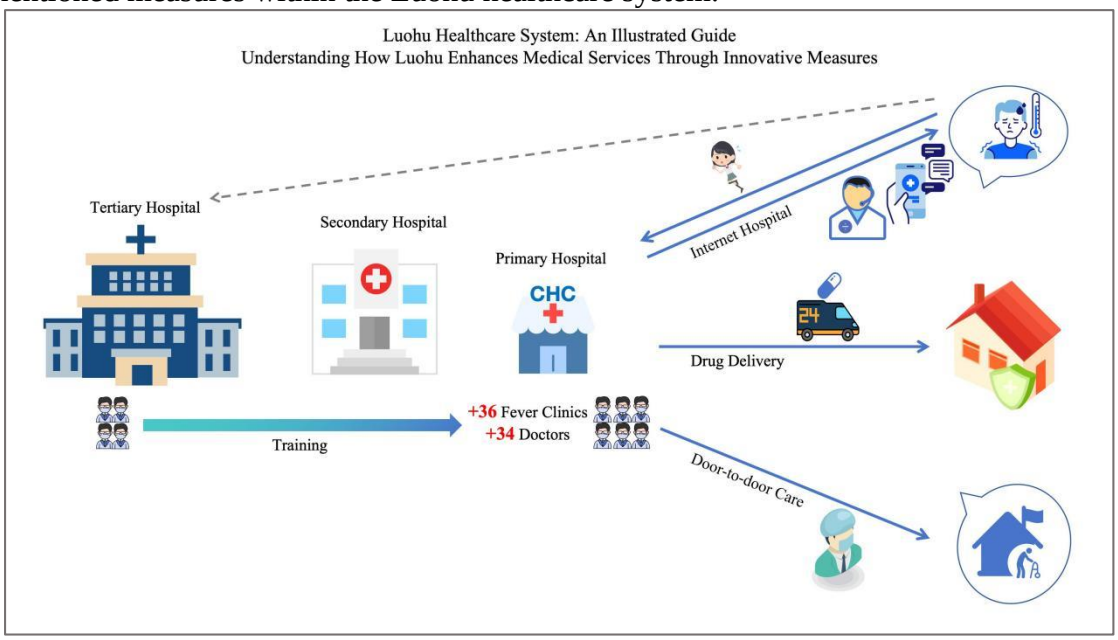

Figure 2: The Luohu healthcare system in fighting the public health crisis

3.2. Empirical results

Between Dec 9th, 2022, and Dec 18th, 2022, a total of 21,775 CHC outpatient visits for fever took place, accounting for approximately 74.25% of the total conducted in the hospital group's fever clinics. Overall, between Dec 9th, 2022, and Jan 5th,2023, there were 66,038 CHC outpatient visits performed, comprising roughly 70.84% at the total fever clinic activity of the Luohu integrated organization.

3.2.1. Change in the visit structure

Between December 9th, 2022, and January 5th, 2023, the volume of outpatient visits at the CHC's fever clinics constituted 65% of the total services provided by the organization, markedly surpassing the regular rate of 48.14%. From December 11 to December 17, 2022, the daily growth rate of the internet hospital's outpatient visits reached 23.16%.

(1) Replacing distant medical visits with proximity visits

Table 1 presents fever patient treatment data in CHCs from Dec 9th, 2022. Until Jan 19th, 2023, when all the doctors returned to the hospitals, CHC visits notably increased compared to the preceding month (Nov 1st to Dec 8th), with a daily average rise of approximately 33.34%, totaling about 1,586 patients per day.

(2) Replacing offline visits with online visits

Table 2 illustrates Luohu integrated organization's initiation of online hospital visit scheduling from Dec 18th, 2022. Between Dec 18th, 2022, and Jan 19th, 2023, there was a notable rise in both online hospital visits and prescriptions compared to the preceding month, especially within the

respiratory department.

Table 2: Quantitative Assessment of Healthcare Visits, Infections Avoided, and Cost Savings

	Category	Pre	After
CHC	The total visits(average per day)	4758 [3338,6973]	6345 [2935,8608]
	The fever clinic visits(average per day)	0	2005 [588,5047]
	Average daily number of avoided infections	428	
	Related cost expenditure of an average daily number of avoided infections, US Dollar	9383.46	
Internet Hospital	Internet Hospital total visits(average per day)	661 [428,2174]	999 [238,2834]
	Prescriptions(average per day)	269 [16,1398]	574 [102,1790]
	Internet Hospital respiratory fever visits(average per day)	19 [4,33]	96 [8,528]
	Average daily number of avoided infections	62	
	Related cost expenditure of an average daily number of avoided infections, US Dollar	1352.86	

Note: The Range of the Number of Visits is Indicated in Parentheses

3.2.2. Infection avoided and cost saving

Table 1 presents the basic analysis results: The "off-peak" services offered by CHCs and Internet hospitals can effectively prevent the transmission of infections by infected individuals, thereby avoiding related cost expenditures.

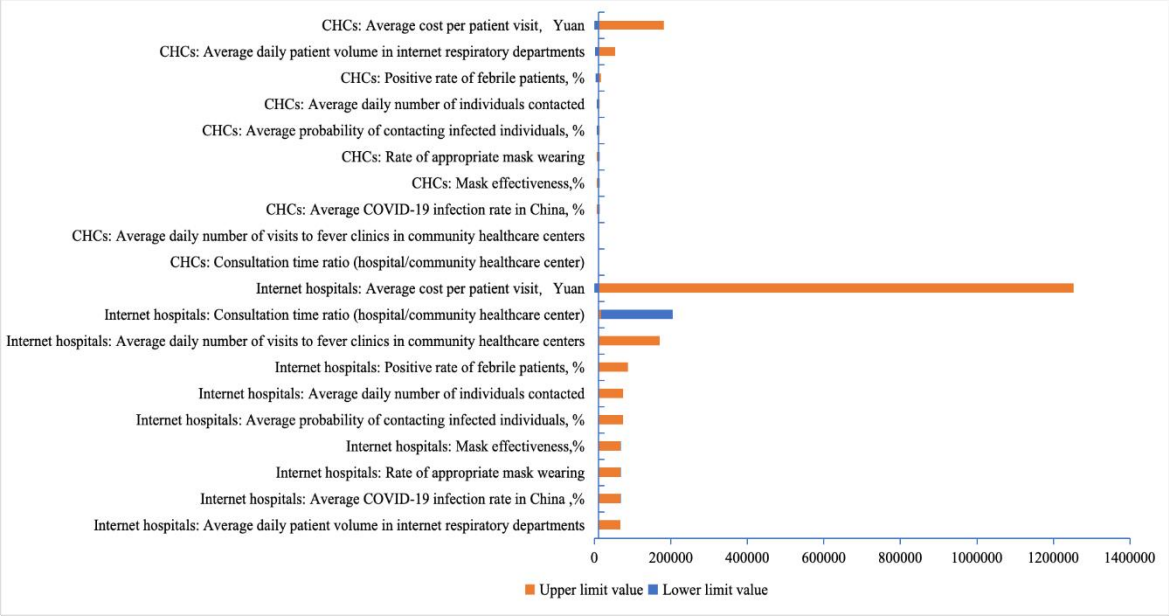

Figure 3: Sensitivity analysis results for CHCs and Internet hospitals

Figure 3 depicts the deterministic sensitivity analysis results: using cost expenditure as the outcome measure, the results reveal that the cost of treatment is the parameter that has the greatest impact on the results for both CHCs and internet hospitals. Furthermore, the clinic time of CHC visits and hospital visits, average daily number of visits, and proportion of positive cases among fever patients also had an impact on the results.

3.2.3. Doctors' Satisfaction

Every participant conveyed satisfaction with the assistance provided: 50% expressed moderate satisfaction, while the remaining 50% indicated high satisfaction levels. Furthermore, all doctors underwent training before supporting grassroots hospitals, with nearly all engaging in online training activities. All doctors smoothly transitioned from medical specialists to general practice. Additionally, 52.9% of doctors reported experiencing occasional or frequent feelings of anxiety, irritability, or unease during their work. Similarly, 61.8% of doctors reported occasional or frequent sensations of tiredness, headache, decrease in energy and physical strength while working. They faced a substantial workload and required both physical and psychological support. (See Supplementary Table 1)

3.2.4. Patients' Satisfaction

Among the 209 patients surveyed, satisfaction among male patients was notably higher at 97.6% compared to satisfaction among female patients. Patients with urban resident medical insurance showed a 100% satisfaction rate. Those choosing CHCs reported higher satisfaction (98.4%) than those visiting tertiary hospitals. The satisfaction rate reached 99.6% when physicians closely attended to patients' medical needs. Patients consulting specialized doctors in social health reported a satisfaction level of 99.4% compared to others. Furthermore, patients valued reliable services, including the timely resolution of consultation needs through professional services provided by physicians and the comprehensive maintenance of medical records ($P < 0.05$). Refer to Supplemental Table 3 for a detailed exploration of findings. (See Supplementary Table 2)

4. Discussion

Globally, the sudden outbreak of COVID-19, exemplified by the case in Wuhan, China, led to severe strain on medical systems worldwide[30-32]. Since Dec 2022, a significant COVID-19 epidemic has emerged in China following the easing of prevention and control measures, then a swift virus spread and heightened medical demand[33-36]. A pertinent study revealed that in Shenzhen, 72.8% of individuals attempting to procure medications encountered unavailability, with 49% facing challenges in their pursuit. Individuals who secured treatment experienced, on average, an additional 0.39 days of absence from work compared to those who encountered no obstacles in receiving care[37]. Luohu health care system stands out with a significant majority of patients (93.5%) strongly agreeing they could quickly find nearby CHCs when experiencing fever, a stark contrast to the city's overall struggles. This accessibility, coupled with a high rate of satisfaction with online appointment services (95.3%), illustrates Luohu's superior performance in healthcare delivery during the pandemic.

Our study reveals that the Luohu healthcare system's response was not only more adaptive than individual medical facilities' efforts but also surpassed other integrated care organizations in crisis management[38-40]. This Luohu model sets a precedent for integrated healthcare systems in emergency response scenarios. The key factors behind Luohu's success lie in its rapid response capabilities, integrated management approach, and emphasis on online medical services and community engagement, which have effectively enhanced the accessibility and efficiency of healthcare services. Additionally, personnel training and optimized resource allocation have supported its exceptional performance during the pandemic. The Dutch study and Kaiser Permanente Southern California (KPSC) data illustrate the potential of such systems to rapidly adapt[41] and extend healthcare access, particularly through telehealth services[42]. This aligns with our findings in Luohu, where the swift adoption of online medical services and strategic resource allocation effectively managed the surge in fever cases. Furthermore, consistent with the views of He et al. (2022)[43], our observations support the notion that an integrated service system can enhance medical

proficiency and operational efficiency. The Luohu model's ability to quickly adapt to the pandemic by strengthening primary care capabilities and transitioning to an emergency response mode is a testament to the potential of integrated care organizations to manage public health emergencies effectively.

Despite the effectiveness of Luohu's emergency management methods, our study also uncovers challenges that require attention. The elevated workload experienced by healthcare professionals, especially doctors, points to a need for enduring support systems. The risk of burnout and the impact on the physical and mental health of healthcare workers are significant issues that must be tackled to ensure the sustainability of emergency response strategies. While effective in the short term, the current model may not be sustainable in the long term without modifications. Moreover, the potential waste of primary healthcare resources during non-emergency periods suggests a need for a more balanced approach to resource distribution and utilization. In future, medical consortia should focus on devising sustainable healthcare frameworks that can endure the pressures of emergency scenarios while also meeting the demands of routine medical care. This includes investigating innovative healthcare delivery approaches, improving support systems for healthcare workers, and refining resource management to avoid waste.

This study has limitations. The primary limitation is the constrained time horizon of the observation period. The study captures the system's response within a limited window of a month, which restricts the ability to assess the long-term effectiveness and sustainability of the measures implemented. This short-term perspective may not fully reflect the system's adaptability over an extended period or in response to evolving public health challenges. Secondly, the scope of our research does not encompass a comprehensive evaluation involving multiple stakeholders, and the availability of performance and indicator data is limited, potentially affecting the completeness of our assessment. Additionally, the dynamic model we employed is largely based on a combination of assumptions due to the lack of better sources, which may introduce uncertainties into our analysis. The lack of a standardized procedure for evaluating the system's response indicates a gap in the theoretical framework that warrants further investigation. Future research should aim to address these limitations by conducting longitudinal studies over a more extended period and developing a standardized evaluation framework that considers local contexts and needs.

5. Conclusion

This study confirms that an integrated healthcare system, beyond ensuring routine diagnostic and treatment protocols, can effectively and economically reconfigure its systems during crises. This dual capability for peacetime and emergency response enables the provision of prompt and efficient medical services, curbing viral spread and potentially saving numerous lives. As the world braces for future medical emergencies, the lessons learned from the Luohu integrated organization's experience can serve as a valuable guide for integrated care across China and globally.

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Author contributions

YD, ML, DZ, RG, XC, ZF, YY, KW, JL, FG, WY, WT: met the criteria for authorship and contributed to the drafting, revision and finalisation of this paper. YD, WT, RG: revised the final

version. All authors approved the final version.

Patient consent for publication

Not required.

Competing interests

None declared.

Data availability statement

Data are available upon reasonable request. The datasets used during the study are available from the corresponding author on reasonable request.

Supplemental material

The additional file for this article can be found as follows:
Supplemental File 1. Supplemental Tables 1, 2, and 3.

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