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An emerging knowledge management framework adopted by healthcare workers in China to combat COVID-19

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Abstract

This study examines elements of knowledge management (KM) applied during the treatment of the coronavirus disease 2019 (COVID-19) and proposes a KM framework that can be applied to respond quickly to a new virus outbreak. Following a content analysis of the press conferences held in China, this study found that various elements of KM, including strategic KM, the knowledge codification strategy vs. the knowledge personalization strategy, a knowledge-friendly culture, knowledge-based leadership, KM-based human resource management, and KM-related information technologies, were widely used by Chinese authorities and healthcare workers to improve treatment effectiveness for COVID-19 patients. This paper provides a unique case study on how KM helps the government and the healthcare workers to respond to an unexpected public hygiene crisis.[i]

1 | INTRODUCTION

Although knowledge of modern medicine has accumulated exponentially compared with several decades ago, people were initially ignorant of the coronavirus disease 2019 (COVID-19). COVID-19 is a disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that was first detected in December 2019 in Wuhan, Hubei Province, China. The World Health Organization (2020) announced a COVID-19 pandemic on March 12th, 2020, as 125,260 confirmed cases were reported from 118 countries and regions. As of May 27, 2022, the number of people infected had surged over five hundred and twenty-five million (525,467,084) and 285,171 had died globally (WHO, 2022). Historically, unknown epidemics are a great threat to human beings because nothing is known about the disease when it emerges. The more knowledge about a new epidemic and the faster this knowledge is obtained,

the fewer victims there are. As such, more knowledge about an epidemic can save more people's lives and prevent more people from suffering from misery.

It is a significant challenge for people to combat COVID-19 without sufficient knowledge about it. Therefore, healthcare workers did not know how to treat patients infected with COVID-19 at the early stage of the breakout. COVID-19 is severe pneumonia, which can develop into an acute respiratory distress syndrome. Elderly people and those with chronic diseases or comorbidities, such as hypertension and diabetes, are more likely to experience serious effects which are difficult to treat. The COVID-19 virus not only attacks a patient's lung but also invades other organs, such as the heart, kidney and liver, and even the immune system. As the virus quickly duplicates in these organs and damages people's immune systems, the patient's condition can deteriorate suddenly. However, 94% of the people infected with COVID-19 in Mainland China have recovered (Xinhua, 2020a) as

healthcare workers have gradually become equipped with the knowledge needed to combat the disease.

It is a widely held view that knowledge management (KM) is important for healthcare workers (Kim et al., 2012) and if properly applied, can have a positive effect on hospital performance (Gowen et al., 2009) since healthcare workers are typical knowledge workers who solve complex problems based on knowledge actions (Reinhardt et al., 2011). For example, information technologies (IT) for knowledge codification and collaboration can lead to successful changes in the healthcare sector (Dixon et al., 2017). However, understanding the role of KM in the treatment of new epidemics is poor because a limited number of studies were visible. Previous KM studies concerning epidemics tended to summarize lessons learnt when the infectious disease was diminishing, as in the case of SARS (e.g., Devadoss et al., 2005; Hawryluck et al., 2005; Webster, 2020); however, these post-hoc summaries lacked a systemic analysis of the importance of KM elements for the prevention and control of new epidemics. Therefore, this study explores the elements involved in the treatment of the COVID-19 pandemic and contributes to the response to a public health crisis by offering a feasible and effective KM framework that can be used to handle the crisis as it continues to unfold. Following a briefing of the background and objectives of this study in this section, Section 2 outlines concepts of KM elements and identifies the research gaps. Section 3 introduces the research method applied in this study and Section 4 presents and discusses the findings. Section 5 concludes with contributions, limitations, and recommendations for future research.

2 | CONCEPTUAL FRAMEWORK

KM elements, also known as KM enablers or practices refer to management practices that aimed to support efficient and effective management of knowledge for organizational benefit (Andreeva & Kianto, 2012, p.620). After investigating 160 KM frameworks around the world, Heisig (2009) found that an underlying consensus concerning KM elements descriptions and these KM elements can be categorized into four groups, namely, management process-oriented factors (including strategy, goals and measurement), human-oriented factors (including culture, people, and leadership), technology-oriented factors (including infrastructure and applications), and organization-oriented factors (including processes and structures). The findings of Heisig (2009) provide a deeper understanding of KM elements, which are widely covered in KM research, such as those by Inkinen (2016), Liu et al. (2020), and Kianto et al. (2014), etc. In addition, it is difficult to achieve the success of organizations without sufficient support of KM elements (Davenport et al., 1998) because the KM elements facilitate KM activities in organizations and produce value for employees

TABLE 1 Definition of KM elements

KM factors	KM element	Definitions
Process-oriented factors	Strategic KM	Strategic KM emphasizes formulating organizational strategies, making decisions based on knowledge and communicating these strategies to employees comprehensively (Hussinki et al., 2017; Liu et al., 2020)
	Knowledge codification strategy	Knowledge codification strategy is concerned with capturing, codification and storage of explicit knowledge with the application of technologies (Choi & Lee, 2012).
	Knowledge personalization strategy	The knowledge personalization strategy focuses on increasing the communication of tacit knowledge through the interaction and social networks of people (Hasan et al., 2015).
Human-oriented factors	Knowledge friendly culture (KFC)	A KFC is the perceived belief and norm of employees in which employees are free to share their knowledge and collaborate with each other smoothly and where learning and innovation are highly valued (Liu et al., 2021).
	Knowledge-based leadership	Knowledge-based leadership is the capability of leaders to influence others on KM processes and activities (Liu, 2022).
	Knowledge-based human resource management (HRM)	Knowledge-based HRM refers to manage human resources by involving KM, such as recruiting workers based on their knowledge and skills, motivating and praising employees based on their knowledge contribution to the organization, and providing training courses (Hussinki et al., 2017; Kianto & Andreeva, 2014).
Technology-oriented factors	KM-related information technologies (IT)	KM-related IT refer to tools, platforms, and infrastructures developed by IT that are applied to support KM activities in organizations (Liu, 2021).
Organization-oriented factors	Knowledge-based organizational structure	A knowledge-based organizational structure refers to an organizational design that facilitates knowledge processes and activities (Liu, 2021).

and organizations. Up to now, there is still no widely accepted definitions of KM elements in the literature; Liu (2021) outlined a set of definitions for KM elements based on a large number of empirical studies on KM and organizational performance relationships. These definitions are shown in Table 1.

Prior research paid little attention to the role of KM in preventing and controlling a pandemic; most research focused on the lesson learnt from combating epidemics in a KM perspective. On the other hand, some studies proposed KM frameworks for the daily work of healthcare workers, for instance, Ghosh and Scott (2006) mainly focused on organizational structure, culture, and technology to examine nurses' performance without considering strategic KM, KM strategies, and knowledge-based HRM. Raymond et al. (2017) proposed an IT-enabled absorptive capacity-performance framework for healthcare workers. Their framework was limited because they merely examined the role of IT in KM activities of healthcare without assessing the human-oriented factors, such as culture, leadership, and knowledge-based HRM, the organization-oriented factors, such as knowledge-based organizational structure, and process-oriented factors, such as strategic KM and KM strategies. Instead of involving KM elements, Jørgensen et al. (2019) developed a framework supporting knowledge sharing in healthcare through communities of practice. Still, current studies have neglected many KM elements in their frameworks and did not emphasize the role of KM in helping to respond to public health crisis. Therefore, this study tries to provide a feasible KM framework to respond to the COVID-19 pandemic, especially in the treatment of COVID-19 patients.

3 | RESEARCH METHOD

To examine KM elements during the treatment of COVID-19, this study applies a qualitative research strategy and analyses data collected from the press conferences held by Chinese authorities.

3.1 | Raw data

The Press Conference of Joint Prevention and Control Mechanism of the State Council, People's Republic of China, has been held every day since 5th February 2020. At the press conference, the chairman introduced all the measures and policies that had been put in place to contain COVID-19 and to sustain people's lives and economic activities in China. Briefings of the State Council Information Office (SCIO), People's Republic of China, were also held when necessary to introduce the progress of COVID-19 containment and treatment. Following the chairman's introduction to the topic, journalists asked questions and speakers offered answers.

Of the 87 press conferences held between 22nd January 2020 (the first states briefing on COVID-19 containment) and 31st March 2020, 23 were related to COVID-19 medical treatment (including seven press conferences from SCIO). We have coded and analyzed the content of the 23 press conferences to explore the KM elements of the COVID-19 treatment.

3.2 | Content analysis and coding rules

Content analysis is a popular method that is applied to analyse texts (or other symbolic materials) for social science purposes (Duriau et al., 2016; Shapiro & Markoff, 1997). Content analysis is appropriate for this study because this study is based on data entirely drawn from press conferences held in China during a specified period. Including the introductive content from the chairman of the press conferences, each pair of questions and answers were coded, but only the content of the introduction and answers were analyzed. The first four digits of the code are the date and month of the press conferences. The next digit is the number of the press conferences on that date, followed by the item number (number of questions and answers or introductive content) of the content of the press conferences. The next code is an abbreviation of KM elements followed by the name of the speaker. We clustered these elements into different KM element categories based on Liu's (2021) work because the work of Liu (2021) extends Heisig's (2009) classification to a more detailed approach (Figure 1).

4 | FINDINGS AND DISCUSSIONS

Confronting the unknown virus battle, medical staff in China demonstrated their capability to defeat the virus based on their knowledge and effort. As of 16th April 2020, 77,844 COVID-19 patients in Mainland China were discharged from the hospital upon recovery. As Figure 2 shows, the number of people infected daily started to decline after reaching a peak on 20th February 2020; the daily number of recovered patients climbed and then declined as fewer people became infected. The daily number of fatalities also declined, as displayed in Figure 3. Figure 4 shows that even though the total number of confirmed cases increased, the total number of recovered patients also increased, and the total number of fatalities remained stable. These figures indicate that the treatment of COVID-19 became more successful as medics developed sufficient knowledge to combat the virus and bring the epidemic in China under control.

Adopting Heisig's (2009) and Liu's (2021) classifications of KM elements and based on a wealth of evidence extracted from the press conferences of mainland China, this study found an emerging KM framework in which (1) the objectives and principles of rescue were based on strategic KM approaches; (2) the knowledge codification strategy and the knowledge personalization strategy were developed simultaneously; (3) a KFC was well formulated among the healthcare workers; (4) the officials from authorities and managers from hospitals in different levels demonstrated strong knowledge-based leadership; (5) knowledge-based HRM; and (6) KM-related IT were widely applied for KM activities to help Chinese healthcare workers to combat COVID-19.
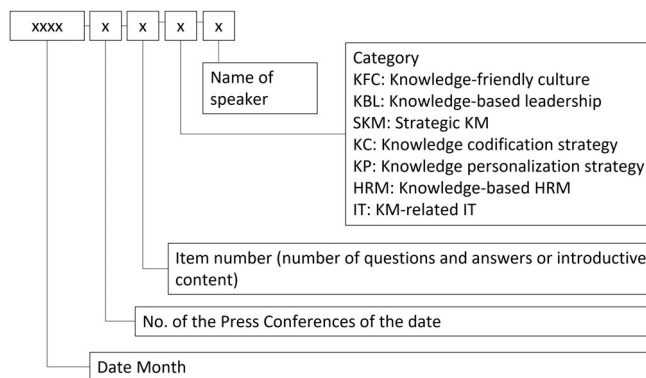
FIGURE 1 Breakdown of the coding rules for the content analysis
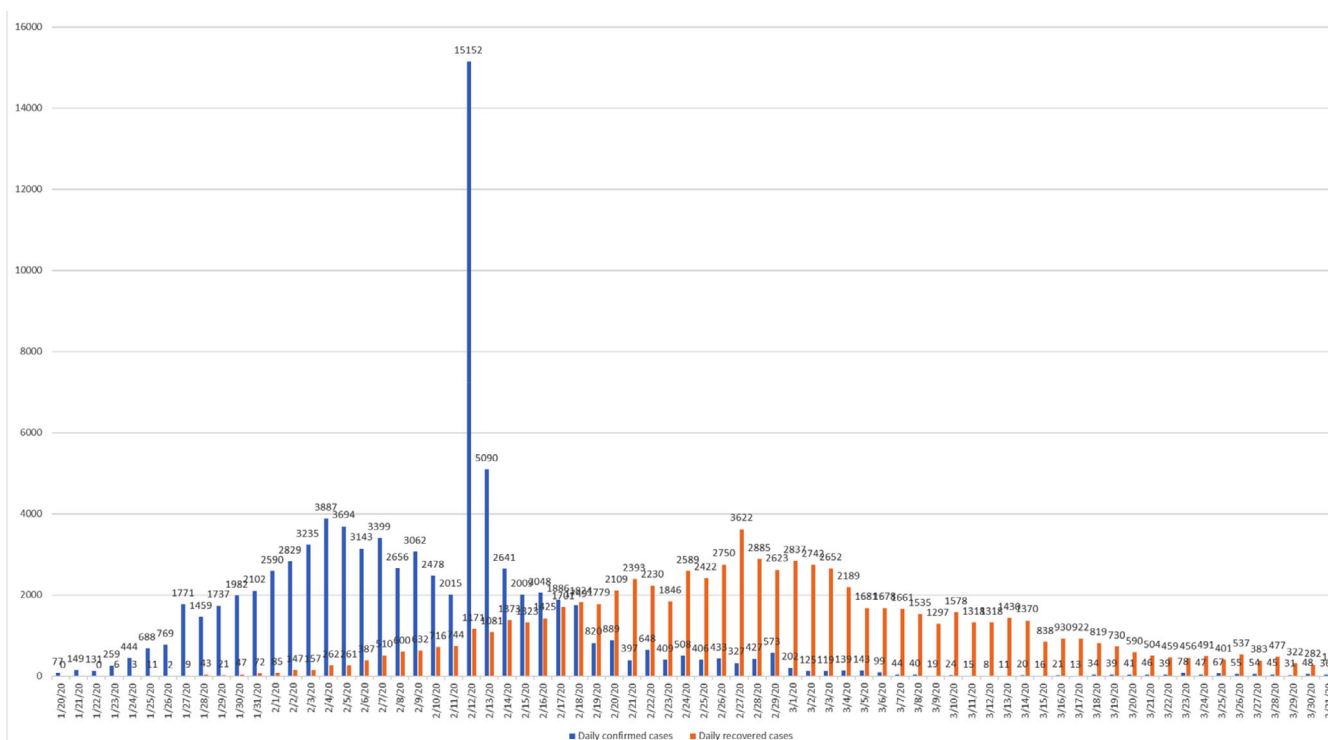

FIGURE 2 Daily confirmed cases and recovered cases in mainland China between 20th January and 31st March 2020 (Source: Daily Briefing, National Health Commission, P.R. China[j]) [Colour figure can be viewed at wileyonlinelibrary.com]

4.1 | Strategic KM

Strategic KM emphasizes formulating organizational strategies, making decisions based on knowledge and communicating these strategies to employees comprehensively (Hussinki et al., 2017), which is a critical success factor of KM (Liu et al., 2020). This study offers evidence of applications of strategic KM to contain COVID-19. Chinese government highlighted the importance to put people's lives and health first and try its best to protect and save its people's live by adopting a science-based approach. Based on knowledge of previous epidemics, National Health Commission, China, proposed a principle of early identification, early isolation, early diagnosis and early

treatment to contain COVID-19 and the principle of "Four Concentrations" to concentrate (1) patients, (2) medical experts, (3) resources and (4) treatment into special local centers[ii] (0502-1-1-SKM&KC-Yanhong Guo). The objective of the treatment was to enhance the recovery rate and decrease mortality of the COVID-19 patients (0502-1-1-SKM&KC-Yanhong Guo). Developed by the strategic KM approach, these principles and objectives were communicated to the public and healthcare workers and provide clear guidelines and strategy for China's COVID-19 containment and treatment. As Yanhong Guo said, "…'Four Concentrations' are the critical principles to treat COVID-19 patients, especially for server cases and…. the principle of 'Four Concentrations' is also the general guideline for the whole
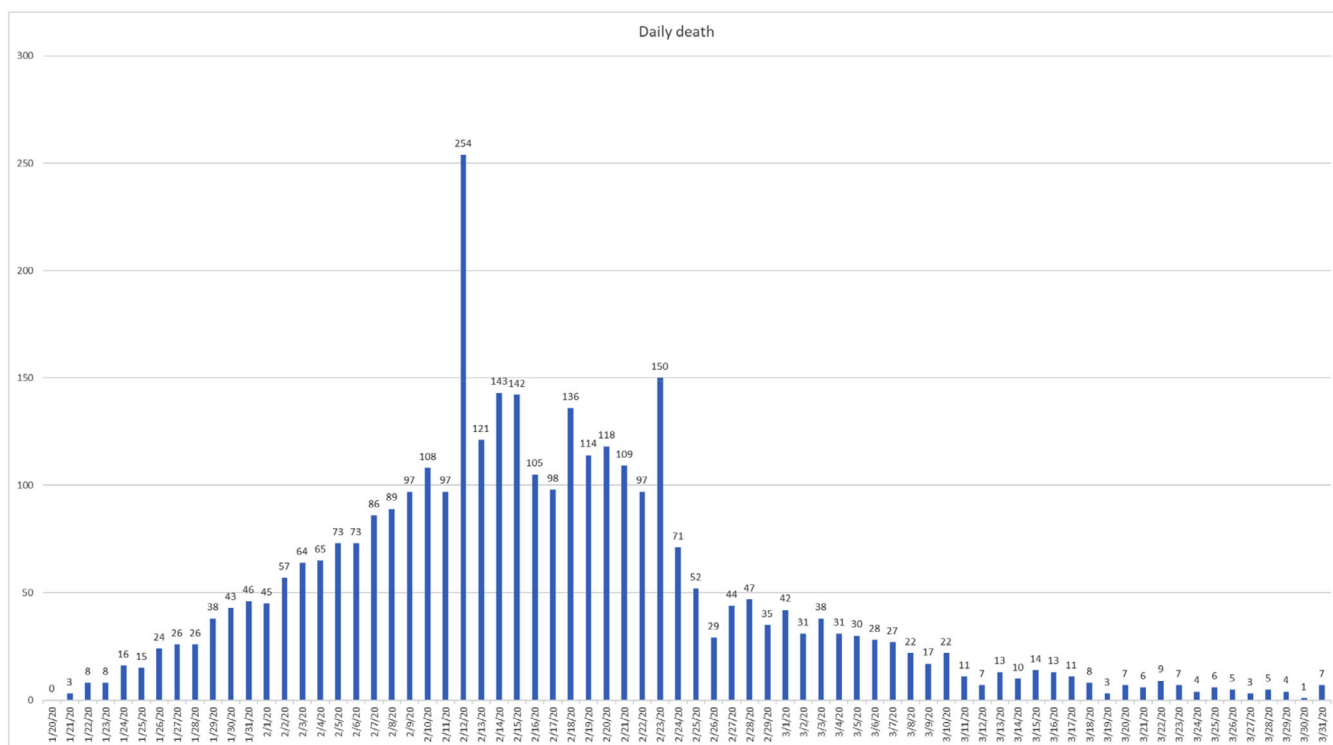
FIGURE 3 Daily deaths between 20th January and 31st March 2020 (Source: Daily Briefing, National Health Commission, P.R. China [see end note i]) [Colour figure can be viewed at wileyonlinelibrary.com]

nation" (0702-2-12-KFC&KP&SKM-Yanhong Guo). The treatment objectives and "Four Concentrations" principles provide a mechanism to foster KM elements, first, concentrating COVID-19 patients (including asymptomatic cases) prevents others from infection and enables healthcare workers to closely help the patients and deepen understanding of COVID-19 at the site; second, concentrating experts enabled experts to easily share knowledge to frontline healthcare workers through KM elements. While in turn, the KM elements support healthcare workers to achieve treatment objectives because healthcare workers can obtain, create, share, apply, and store knowledge through KM elements in the COVID-19 patient treatment processes, as shown in Figure 5.

4.2 | KM strategies

Knowledge is categorized into explicit knowledge and tacit knowledge (Nonaka & Takeuchi, 1995). Accordingly, while the knowledge codification strategy is concerned with capturing, codification, and storage of explicit knowledge with the application of technologies (Choi & Lee, 2012), the knowledge personalization strategy focuses on increasing the communication of tacit knowledge through the interaction and social networks of people (Hasan et al., 2015). This study found that the knowledge codification strategy and the knowledge personalization strategy successfully aligned with treatment objectives and principles in China by facilitating knowledge sharing, storage, and application among healthcare workers.

4.2.1 | The knowledge codification strategy

Explicit knowledge about treatment for COVID-19 was codified as the *Clinical Protocol for the Diagnosis and Treatment of COVID-19* (refer to clinical protocol hereafter) to guide doctors in the diagnosis and treatment of COVID-19 patients. The clinical protocol, which has been updated to the seventh version since 16th January 2020, can be downloaded from the website of the National Health Commission, P.R. China, for free. Figure 6 shows that frequent updates of knowledge in the form of clinical protocols have been made in a short period. A clinical protocol was the collective knowledge of experts (0502-1-1-KC-Yanhong Guo, 0702-2-12-KFC&K-Yanhong Guo) including new and effective treatment for patients (0502-1-2-KC-Yanhong Guo). The newest clinical protocol was interpreted by experts to the public during a press conference (0502-1-2-KC-Yanhong Guo), and healthcare workers in the whole of China refer to the latest clinical protocol during their work (1502-1-1-HRM&KP&KC-Hesheng Wang). Therefore, the collective explicit knowledge is universally shared and communicated to healthcare workers to ensure the quality of treatment.

First-hand knowledge of frontline health care workers is extremely valuable and unique at the beginning of an unknown epidemic; therefore, Chinese experts have published many research papers about COVID-19 (Xiang et al. (2020) to share their knowledge with the community. The frontline doctors were also encouraged to codify their explicit knowledge into research papers when they acquired new knowledge during the treatment processes (1502-3-5-KFC&IT&KC-Yuanbin Wu) and write them in English to share
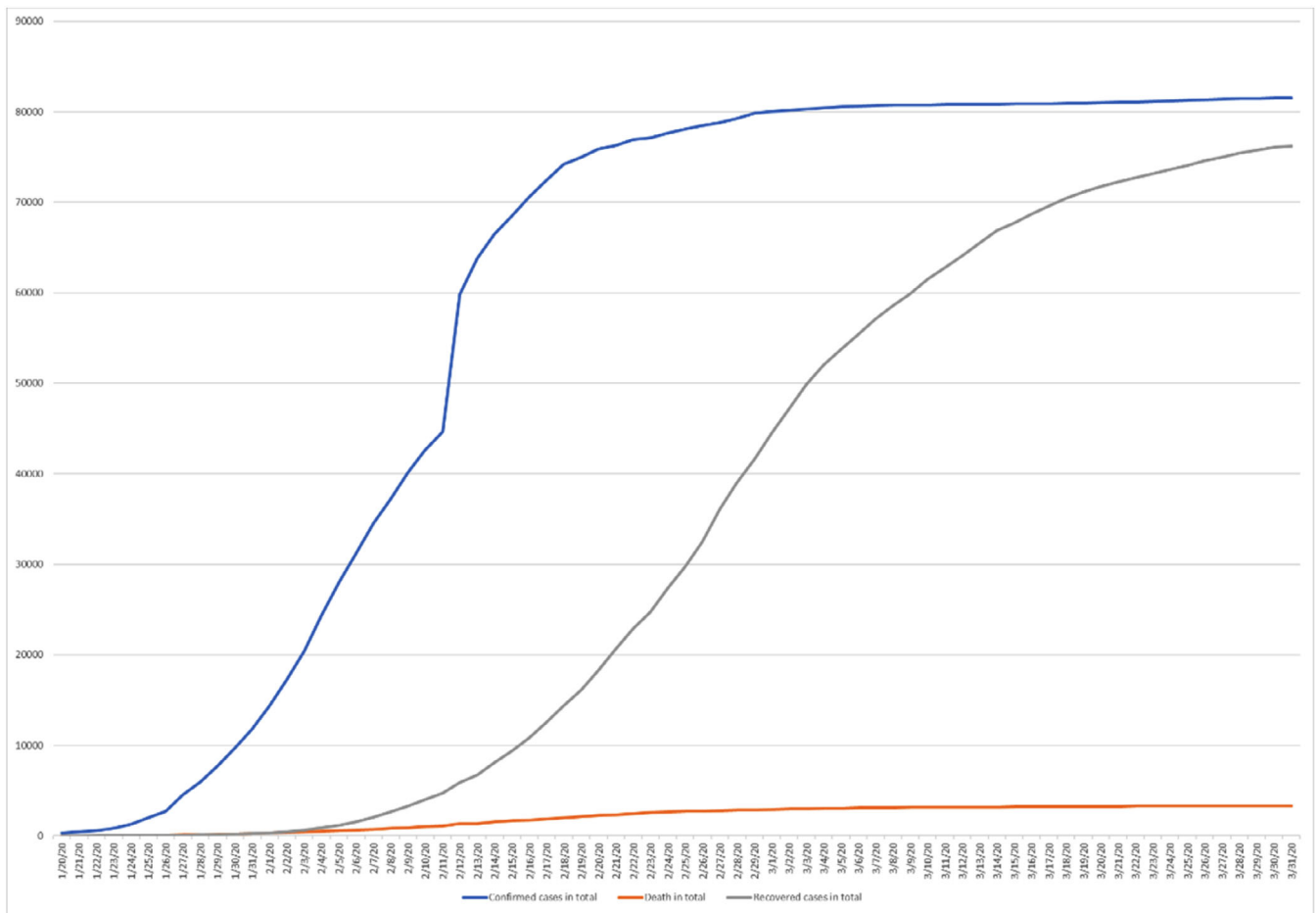
FIGURE 4 Total confirmed cases, totally recovered cases and total deaths in mainland China between 20th January and 31st March 2020 (Source: Daily Briefing, National Health Commission, P.R. China [see end note i]) [Colour figure can be viewed at wileyonlinelibrary.com]
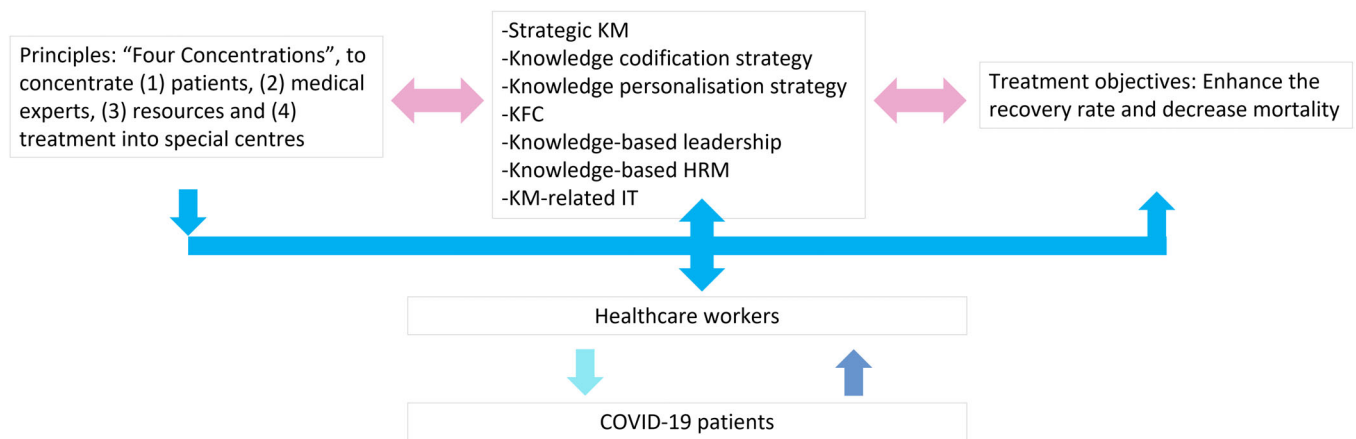

FIGURE 5 A framework that knowledge enables healthcare workers to combat COVID-19 [Colour figure can be viewed at wileyonlinelibrary.com]

internationally by the authority (2603-2-9-KFC&IT&KC-Nanping Xu). The codified knowledge is by-products of treating COVID-19 patients, but it helps global healthcare workers to understand and combat COVID-19. Over 700 research papers have been published in Chinese or English in 99 journals, including *The Lancet* and *The New England Journal of Medicine*, and stored on the COVID-19 academic research communication platform[iii] as of 25th March 2020 (2603-2-9-KFC&IT&K-Nanping Xu). The number of papers increased
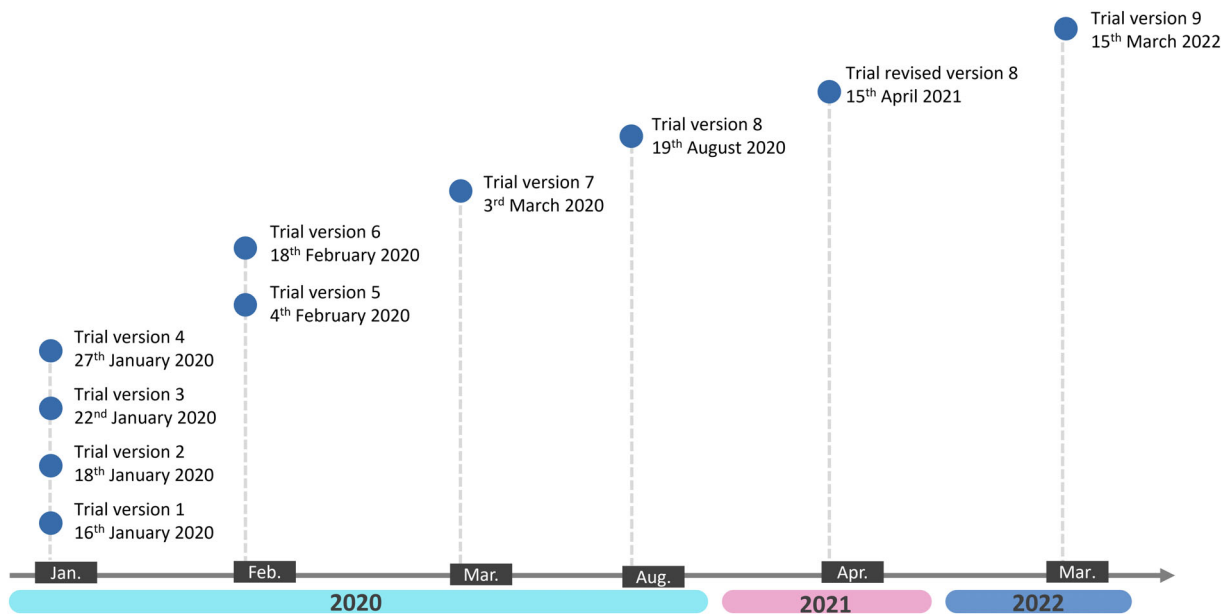
FIGURE 6 Update of clinical protocols for the diagnosis and treatment of COVID-19 [Colour figure can be viewed at wileyonlinelibrary.com]

to 842 in 122 journals and more than 2.7 million readers have read papers from the platform as of 12th April 2020 (Chinese Medical Journal Network, 2020), as shown in Figure 7. Besides codifying explicit knowledge into research papers, experts' explicit knowledge and training courses related to COVID-19 treatment and containment were also recorded as videos and shared with other countries via a knowledge center (an IT-based knowledge repository) (0204-1-11-KC-Mingzhu Li). In addition, explicit knowledge about other aspects of treatment has been codified as rules and recommendations, such as *nursing for severe COVID-19 patients and TCM guidance for recovering patients* (2902-1-7-HRM&KC-Na Guo). These codified documents,
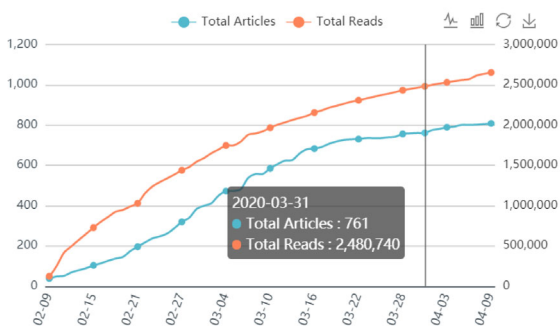

FIGURE 7 Overview of academic research communication platform 2020 (Chinese Medical Journal Network, 2020) [Colour figure can be viewed at wileyonlinelibrary.com]

including clinical protocol, research papers, and other documents are valuable knowledge for deepening people's understanding of COVID-19, especially at the current stage when people are struggling to save people's lives.

4.2.2 | The knowledge personalization strategy

The knowledge personalization strategy enables healthcare workers to quickly obtain explicit knowledge from others in terms of COVID-19 treatment, which significantly improves their job performance. COVID-19 is severe pneumonia causing many syndromes, which needs healthcare workers' tacit knowledge to find the best solution for COVID-19 patients. The tacit knowledge is difficult to codify (Jisr & Maamari, 2017), but it can be shared and transferred among healthcare workers via a knowledge personalization strategy (Maier & Remus, 2002). This study revealed that tacit knowledge has been shared intensively by healthcare workers in different forms, including face-to-face and remote expert visits, consultations and guidance (see, e.g., 1302-1-3-KP&HRM-Yanhong Guo, 1502-1-8-HRM&KP-Yahui Jiao, 0603-3-1-KP&KC&KFC-Xiangyang Ding, 2902-1-12-KC&KP&KFC&IT-Guiqiang Wang, 0203-1-3-KC&KP&IT-Jingyuan Chen) when they found difficulty in treating patients. The experts shared their tacit knowledge with frontline doctors and offered solutions for severe patients. In addition, face-to-face and remote regular meetings of discussion about complex cases were well organized between experts and healthcare workers (1502-1-4-HRM&KP&KC-Yahui Jiao). From the discussions with experts, healthcare workers can obtain knowledge on how to treat complicated cases efficiently. Such intensive tacit knowledge sharing enables healthcare workers to further understand COVID-19 treatment and improve their capability to save patients' lives. The knowledge personalization strategy facilities smooth knowledge sharing and transferring

TABLE 2 Role of KM elements in combating COVID-19

KM element	How it helps healthcare workers
Strategic KM	• Objectives and principles for COVID-19 treatment were developed based on knowledge and science. • Containment and treatment strategies were well communicated. • With the help of strategic KM, it has deepened the understanding of healthcare workers in terms of treating patients.
Knowledge codification strategy	• Frequent update of Clinical Protocol for the Diagnosis and Treatment of COVID-19 by the experts enables frontline healthcare workers to obtain the newest knowledge to treat COVID-19 patients • Intensive contributions to medical research of healthcare workers support global COVID-19 prevention and control. • Continuously codifying knowledge into different types of documents improves the job performance of healthcare workers
Knowledge personalization strategy	• Face-to-face and remote experts' consultation, visit and guidance as well as case discussion meetings facilitate tacit knowledge sharing and transferring. Therefore, healthcare workers can quickly obtain knowledge to provide treatment solutions to COVID-19 patients.
KFC	• Knowledge sharing culture enables intensive knowledge sharing among healthcare workers. • Collaborative culture helps healthcare workers seamlessly collaborate. • Innovative culture support healthcare workers to create knowledge and find new methods to treat patients
Knowledge-based leadership	• Leaders participated in KM, demonstrating powerful KM leadership. • KM activities, such as knowledge sharing are encouraged by leaders. • Leaders supported KM projects, e.g., providing enough resources for research and development, which helped healthcare workers to successfully create and obtain knowledge.
Knowledge-based HRM	• Organizing an expert team enables easily knowledge sharing between the experts and frontline healthcare workers. • Summoning healthcare workers to Hubei Province to accumulate knowledge to cope with the pandemic. • Providing mandatory training courses help healthcare workers to obtain new knowledge.
KM-related IT	• Knowledge repositories were developed so that knowledge was stored for easy access for healthcare workers. • Video conferences, teleconferences, and 5G network remote consultation systems were implemented for tacit knowledge sharing among healthcare workers. • Intelligent assistant diagnostic systems, artificial intelligence, and big data analytics were adopted to create knowledge for healthcare workers.

between experts and healthcare workers so that healthcare workers can devise the best treatment plan for COVID-19 patients.

4.3 | KFC

A KFC is the perceived belief and norm of employees in which employees are free to share their knowledge and collaborate with each other smoothly and where learning and innovation are highly valued (Liu et al., 2021). The content analysis showed that KFC was effectively developed among the healthcare workers as knowledge-sharing environments were well established among healthcare workers from different hospitals (0403-1-7-KFC&HRM&KBL-Haichao Li) and those within the same hospitals (1603-1-1-KFC&KP&IT-Bin Du). For instance, Dr Bin Du's team in Wuhan discussed complex cases with their colleagues at Peking Union Medical College Hospital in Beijing via weekly teleconferences to determine the best ways to treat severe patients (1603-1-1-KFC&KP&IT-Bin Du). In addition, several academicians and their teams, such as Nanshan Zhong, Lanjuan Li, and Chen Wang, actively participated in medical treatment with frontline doctors offering consultation and guidance for patients with severe conditions (0702-2-12-KFC&KP-Yanhong Guo). Onsite visits and consultations among experienced doctors were also popular for COVID-19 medical treatment (1603-1-1-KFC&KP&IT-Bin Du). Dr Bin Du said, "I spent the last two and a half days visiting five different hospitals

in five cities (Hubei Province) to review the most critically ill patients with COVID-19 there." In this way, the knowledge of these academicians and experts was transferred to frontline healthcare workers effectively and in time to save many patients.

Second, healthcare workers seamlessly collaborated to save patients' lives. As the COVID-19 virus attacks multiple organs of human beings, patients might get several syndromes concurrently leading to comorbidities, making medical treatment extremely tough. Thus, specialists from multi-disciplines (0403-1-7-KFC&HRM-Jie Qiao), such as the respiratory department, infectious department, intensive care unit (ICU), cardiology department, hematology department, and nephrology department (2303-1-17-KFC-Guiqiang Wang) worked together and integrated their knowledge to find the best solution for the patients (1603-1-2-KFC-Xiaowei Yan, 1603-1-3-KFC-WeiCao). Additionally, practitioners in Western medicine and traditional Chinese medicine (TCM) collaborated to offer treatment plans for the patients to achieve better treatment performance (2303-3-8-KFC-Qingquan Liu). As Dr Bin Du said,

> We're working together with our colleagues from the traditional Chinese medicine department.... That traditional Chinese medicine works quite well in patients with mild disease and in those who have been recovering from critical illness... we should learn from each other (1603-1-6-KFC-Bin Du).

With the diversified collaboration of these healthcare workers, knowledge about the medical treatment for COVID-19 was shared and accumulated rapidly, thus improving the recovery rate.

Third, innovative solutions were developed and quickly applied in the treatment plan. For instance, new treatment solutions, such as convalescent plasma therapy (0702-2-12-KFC&KC-Guiqiang Wang) and stem cell treatment (1502-3-8-KFC-Xinmin Zhang), and drugs, such as chloroquine bisphosphate, favipiravir and some TCM, have already been recommended in clinical protocols. According to Yanhong Guo, "Our new technologies, approaches, including TCM are effective for curing patients and we will continuously summarise these useful experiences into the next clinical protocols... to enhance the recovery rate" (1302-1-16-KC&KFC-Yanhong Guo). Equipping healthcare workers with the latest knowledge ensured they were prepared to offer an efficient treatment to patients. Overall, KFC helps healthcare workers by creating an intensive knowledge sharing, seamlessly collaborative, and innovative culture so that healthcare workers can easily share, obtain, create, and apply knowledge.

4.4 | Knowledge-based leadership

Effective leadership is crucial to respond to a crisis (Fred Garcia, 2006) and a major enabler for the success of KM (Cegarra-Navarro & Cepeda-Carrión, 2010). Knowledge-based leadership is the capability of leaders to influence others on KM activities (Liu, 2021). This study showed that powerful knowledge-based leadership was demonstrated by the leaders of Chinese governments and hospitals. The management teams of hospitals actively participated in the medical treatment of COVID-19 patients and these managers showed positive attitudes towards knowledge sharing. For instance, Dr Haitao Li, vice president of Peking University First Hospital, claimed: "We set up a mechanism for sharing knowledge and experience between the colleagues from the different hospitals" (0403-1-7-KFC&HRM&KBL-Haichao Li). These Chinese medical scientists were also encouraged to share knowledge with healthcare workers in other countries, thus allowing knowledge about COVID-19 to be shared with more than 100 countries and over 10 international organizations before 5th March 2020 (0503-1-1-KFC&KB-Yixing Zeng). Supported by top management teams of the Chinese authorities, research and development projects for innovative techniques and solutions to contain COVID-19 were quickly initiated by companies, institutes and hospitals (1502-3-1-KBL-Yuanbin Wu) and these new treatment methods and drugs were immediately applied as a medical treatment once they were proved to be valid (0603-2-2-KBL&KFC&KC-Yuanbin Wu). However, speakers of the press conferences, who were either executives in hospitals (e.g., Jie Qiao, president of Peking University Third Hospital; Bin Cao, vice-president of China-Japan Friendship Hospital) or management team members of government departments (e.g., Nanping Xu, Vice Minister of Ministry of Science and Technology of the P.R. China; Yuanbin Wu, Director-General of Department of Science and Technology for Social Development, P.R. China), demonstrated strong knowledge-based leadership in KM

activities and provided adequate support for innovation projects. With such effective support from leaders, the healthcare workers could obtain and create knowledge efficiently to ensure patients were treated effectively. Therefore, knowledge-based leadership supports healthcare workers to achieve their objectives through a role model of leaders' KM behavior and endorsement of resources and KM activities in treatment processes.

4.5 | Knowledge-based HRM

Knowledge-based HRM emphasizes the importance of the management of human resources, such as recruiting workers based on their knowledge and skills, motivating and praising employees based on their knowledge contribution to the organization, and providing training courses (Hussinki et al., 2017; Kianto & Andreeva, 2014). This study found that knowledge-based HRM focused on three main aspects in China. First, a powerful expert team, comprising academicians, such as Nanshan Zhong, Lanjuan Li, Chen Wang, Xiaolin Tong, Luqi Huang, Boli Zhang, and Jie Qiao, was organized at the beginning of the epidemic breakout (2201-1-1-KFC&KBL&HRM-Bin Li). The expert team guided the nation's treatment for COVID-19 patients. These experts not only participated in the treatment, but also updated the clinical protocols to guide all the healthcare workers (1502-1-4-HRM&KP&KC-Yahui Jiao). Second, over 42,000 healthcare workers summoned nationwide to Wuhan and other cities in Hubei Province from 24th January 2020 to 1st March 2020 (Wu & Zhao, 2020). Participation of these healthcare workers mitigated the pressure of medical rescue systems of Hubei Province, especially in Wuhan (0203-1-1-HRM-Jingyuan Chen, 2902-1-2-HRM-Yanhong Guo). The patients needed healthcare workers' professional knowledge and help to fight against COVID-19 because the more professional were the healthcare workers involved, the more patients could be saved, especially for those with severe symptoms. For example, as Dr. Qiao Jie said "...some patients had complications like vascular disease, hypertension, diabetes and kidney failure or something. Therefore, it is necessary to harness the collective wisdom of specialists to treat this complicated condition" in a press conference (0403-1-7-KFC&HRM Qiao Jie).

Third, mandatory training courses in terms of avoiding infection within hospitals and of the hospital information management systems being used for COVID-19 patients (Chen et al., 2020) were conducted for the healthcare workers before they started their work to ensure they had a deep understanding of COVID-19 (2902-1-4-HRM-Na Guo, 0203-1-6-HRM-Jingyuan Chen, 0403-1-8-HRM-Jie Qiao). With effective training and monitoring, the healthcare workers were equipped with the necessary knowledge to protect themselves and all of them (except 20 members of the National Health Commission, (Xinhua, 2020b)) returned to their hometowns without infection before 17th April 2020 and the 20 experts have left Wuhan (CCTV Video News Agency, 2020) as hospitalized COVID-19 cases in Wuhan dropped to zero (ChinaDaily, 2020). To support the principle of

concentrating experts and treatment objectives, mobilizing and centralizing the specialists to the center of the epidemic is effective and necessary to enhance the treatment capacity and capability. With the assistance of such a large number of healthcare workers, the epidemic in Wuhan and nearby cities was relieved gradually because the knowledge of these healthcare workers was frequently shared, accumulated and applied to cure patients.

4.6 | KM-related IT

IT are driving force of KM which facilitate KM activities (Alavi & Leidner, 2001) and thereby increase the technology knowledge of healthcare workers (Cepeda-Carrión et al., 2011). KM-related IT refer to tools, platforms, and infrastructures developed by IT that are applied to support KM activities in organizations (Liu, 2021), which are widely used by healthcare workers, for example, Cegarr-Navarro and Cepeda-Carrión (2010), Cegarra-Navarro et al. (2013), and Martinez-Caro et al. (2013). This study showed that KM-related IT were widely deployed as part of the KM activities of healthcare workers, such as knowledge retention, sharing, and creation. First, several open knowledge repositories, such as the COVID-19 academic research communication platform (2603-2-9-KFC&IT&K-Nanping Xu, 1703-1-10-KBL&IT-Xinmin Zhang) and 2019 novel coronavirus resource (2019nCoVR)[iv] (2603-2-9-KFC&IT&KC-Nanping Xu) were developed to store the latest COVID-19 knowledge. Second, besides sharing explicit knowledge from knowledge repositories, tacit knowledge was also widely shared in the form of video conferences and teleconferences. For instance, weekly video meetings were held to discuss the most difficult cases with the experts beyond Hubei Province (1603-1-1-KFC&KP&IT-Bin Du), and 5G network remote consultation systems were applied to enable medics to collaborate and transfer their knowledge to treat patients. For example, a 5G network remote consultation system was implemented to link Huoshenshan Hospital with Chinese PLA General Hospital. This system enabled experts from both hospitals to work together to provide a customized and optimized treatment plan for each patient based on collective knowledge during the consultation (0203-1-3-KC&KP&IT-Jingyuan Chen). Third, artificial intelligence and big data analytics were also deployed to filtrate potential drugs (1502-3-2-IT-Xinmin Zhang) and assist diagnoses (28-2-6-IT-Manqing Wu). For instance, the COVID-19 intelligence assistant diagnoses system based on X-ray and computed tomography photographs of the lung is available for medical workers on the website of the China National Center for Bioinformation.[v] Based on learning 500,000 clinical iconographical materials in advance, this system applied natural language and artificial intelligence in photography analytics to offer intelligent and fast diagnosis of COVID-19 with 95% accuracy. In general, KM-related IT support healthcare workers in terms of knowledge retention, sharing, transferring, application, and creation so that they can collaborate smoothly and acquire knowledge easily to treat patients. A summary of how KM elements help KM healthcare workers is shown in Table 2.

5 | CONCLUSIONS

This study adopted a bottom-up approach to develop a KM framework appeared based on treatments of COVID-19 through content analysis of press conferences held by Chinese authorities. This KM framework includes a set of KM elements, such as strategic KM, the knowledge codification strategy, the knowledge personalization strategy, KFC, knowledge-based leadership, knowledge-based HRM, and KM-related IT, which is very identical to the KM initiatives implemented in a top-down method. On the other hand, Chinese healthcare workers unconsciously adopted these KM elements to combat COVID-19. Chinese authorities developed principles of "Four Early, Four Concentrations" and objectives of "increasing rate of recovery and decreasing mortality" for COVID-19 treatments through a strategic KM approach that is based on knowledge and science for strategic planning. These principles and objectives guide and define the endpoints of the treatment processes. Chinese healthcare workers gradually master the knowledge and skills to treat COVID-19 patients. For instance, the *national clinical protocols for the diagnosis and treatment of COVID-19* were frequently updated by the collective knowledge of experts, which provides diagnosis and treatment of COVID-19 for healthcare workers across the nation to ensure knowledge consistency. However, it is still challenging for healthcare workers to deal with complex cases. For complex cases, healthcare workers collaborate through expert visits, (remote) consultations, and (remote) discussions to find the most appropriate solution for the patients. KFC enables smooth collaboration and knowledge sharing. Training is also commonly conducted to equip knowledge to healthcare workers. KM related-IT, such as remote diagnostic and consultation systems as well as knowledge platforms facilitate knowledge sharing among healthcare workers. Artificial intelligence helps healthcare workers to detect cases more efficiently and accurately. All these KM actions cannot be succeeded without strong knowledge-based leadership of the management teams and authorities. Equipping healthcare workers with knowledge and KM elements is a dynamic process that fills the knowledge gaps of healthcare workers. This work is continuing as there is still much unknown about COVID-19.

By extending KM theory and crisis management, this study offers a unique case study that explores the function of KM elements for dealing with a public health crisis, especially in the treatment of disease, which echoes the belief that knowledge and science can prevent the spread of epidemic (Xing, 2020). This study reveals a framework including seven KM elements that can guide authorities and hospitals who face a similar situation. This study deepens understanding of the role of KM elements in responding to an unexpected pandemic. As part of the framework, authorities should first develop containment and treatment strategies based on knowledge rather than on their political needs before developing KFC and knowledge-based leadership to guarantee knowledge activities. Third, complementary knowledge codification and personalization strategies should be implemented and, fourth, a group of experts should be organized and healthcare workers should be trained to quickly spread knowledge. Finally, KM-related IT should be implemented to facilitate disease treatment. With the support

of KM elements, KM activities, such as knowledge creation, sharing, acquisition, transferring, application, and retention can be more effectively carried out among healthcare workers.

Besides its contributions, this study has some limitations that deserve further examination. First, this study focused on COVID-19 treatment based on data obtained from the press conferences held between 22nd January to 31st March 2020. Future studies might extend the dataset by interviewing doctors and nurses who participated in COVID-19 treatment or by analyzing data about COVID-19 treatment from media and social media to obtain more knowledge. Thus, more KM elements might be found to mature this emerging KM framework into a complete one. For example, the knowledge-based organizational structure was not mentioned in the press conferences, which needs more information from other channels, for example, interviews of healthcare workers. Second, as Chinese medical experts actively share knowledge and collaborate with experts from many countries and organizations, future studies might explore the function of KM elements in the global containment of COVID-19 based on global cooperation. Third, as many countries and international organizations are working together to contain the disease, it might be worth investigating the differences in KM elements between different countries or examining the extent to which the national differences, such as the national culture and economy, affect KM elements in terms of responding to a public health crisis. Finally, successful COVID-19 prevention and control cannot be achieved without the support of citizens. Future studies can investigate the interactions of citizenship behavior and KM elements in affecting pandemic control.

Living in a community of shared future for mankind, everyone is at risk of being infected by the coronavirus, regardless of border, race, and wealth. Knowledge is the invisible weapon that healthcare workers can use to combat the virus and KM elements strengthen the weapon's power. Successful global collaboration for managing knowledge provides a promising way to defeat the human being's mutual enemy COVID-19.

DATA AVAILABILITY STATEMENT
The data that support the findings of this research are available on request from the corresponding author.

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ENDNOTES
i National Health Commission, P.R. China, Daily Briefing, http://en.nhc.gov.cn/DailyBriefing.html

ii Special local centres refer to permanent or temporary hospitals or special infectious hospital or respiratory hospitals that treat COVID-19 patients in each city of China.

iii COVID-19 academic research communication platform, Chinese medical journal network: http://medjournals.cn/COVID-19/index.do

iv 2019 Novel coronavirus resource (2019nCoVR), China National Center for Bioinformation: https://bigd.big.ac.cn/ncov?lang=en

v COVID-19 intelligence assistant diagnoses system, China National Center for Bioinformation: http://ncov-ai.big.ac.cn/

REFERENCES
Alavi, M., & Leidner, D. E. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly*, *25*(1), 107–136.

Andreeva, T., & Kianto, A. (2012). Does knowledge management really matter? Linking knowledge management practices, competitiveness and economic performance. *Journal of Knowledge Management*, *16*(4), 617–636. https://doi.org/10.1108/13673271211246185

CCTV Video News Agency. (2020). Last 20 members of NHC expert team leave Wuhan. [Video]. Youtube. https://www.youtube.com/watch?v=ZOT1PXa0pn0

Cegarra-Navarro, J. G., & Cepeda-Carrión, G. (2010). How to implement a knowledge management program in hospital-in-the-home units. *Leadership in Health Services*, *23*(1), 46–56. https://doi.org/10.1108/17511871011013760

Cegarra-Navarro, J. G., Cepeda-Carrión, G., Wensley, A., & Sánchez-Casado, N. (2013). An application of health-portals to improve electronic listening. *The Service Industries Journal*, *33*(13–14), 1417–1434. https://doi.org/10.1080/02642069.2013.815730

Cepeda-Carrión, G., Cegarra-Navarro, J. G., Martínez-Caro, E., & Eldridge, S. (2011). How can managers in the hospital in the home units help to balance technology and physician-patient knowledge. *International Journal for Quality in Health Care*, *23*(5), 600–609.

Chen, S., Zhang, Z., Yang, J., Wang, J., Zhai, X., Bärnighausen, T., & Wang, C. (2020). Fangcang shelter hospitals: A novel concept for responding to public health emergencies. *The Lancet*, *395*(10232), 1305–1314. https://doi.org/10.1016/s0140-6736(20)30744-3

ChinaDaily (2020) Hospitalized COVID-19 cases in Wuhan drop to zero: Official Retrieved April 30, 2020, from http://www.chinadaily.com.cn/a/202004/26/WS5ea53cd0a310a8b241151b7f.html.

Chinese Medical Journal Network, (2020) Overview and highlights. Retrieved April 12, 2020, from http://medjournals.cn/COVID-19/index.do;jsessionid=88817D6E28CA267C156C16FD3F108C20.

Choi, B., & Lee, J. N. (2012). Complementarities and substitutabilities among knowledge sourcing strategies and their impact on firm performance. *Journal of the Association of Information Systems*, *13*(7), 498–545 Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84864501112&partnerID=40&md5=0c893b1c70f7e950cc58e7090b76d541

Davenport, T. H., De Long, D. W., & Beers, M. C. (1998). Successful knowledge management projects. *Sloan Management Review*, *39*(2), 43–57.

Devadoss, P. R., Pan, S. L., & Singh, S. (2005). Managing knowledge integration in a national health-care crisis: Lessons learned from combating SARS in Singapore. *IEEE Transactions on Information Technology in Biomedicine*, *9*(2), 266–275. https://doi.org/10.1109/titb.2005.847160

Dixon, B. E., McGowan, J. J., & Cravens, G. D. (2017). Knowledge sharing using codification and collaboration technologies to improve health care: Lessons from the public sector. *Knowledge Management Research & Practice*, *7*(3), 249–259. https://doi.org/10.1057/kmrp.2009.15

Duriau, V. J., Reger, R. K., & Pfarrer, M. D. (2016). A content analysis of the content analysis literature in organization studies: Research

themes, data sources, and methodological refinements. *Organizational Research Methods*, 10(1), 5–34.

Fred Garcia, H. (2006). Effective leadership response to crisis. *Strategy & Leadership*, 34(1), 4–10.

Ghosh, B., & Scott, J. E. (2006). Effective knowledge management systems for a clinical nursing setting. *Information Systems Management*, 24(1), 73–84. https://doi.org/10.1080/10580530601038188

Gowen, I. C. R., Henagan, S. C., & McFadden, K. L. (2009). Knowledge management as a mediator for the efficacy of transformational leadership and quality management initiatives in U.S. health care. *Health Care Management Review*, 34(2), 129–140. https://doi.org/10.1097/HMR.0b013e31819e9169

Hasan, A., Mohammed, A. H., Wardi, Y., Heldi, N., & Abdullah, M. N. (2015). Environmental hostility contingencies on the relationship between knowledge management strategy and firm performance. *Jurnal Teknologi*, 73(5), 1–10. https://doi.org/10.11113/jt.v73.4312

Hawryluck, L., Lapinsky, S. E., & Stewart, T. E. (2005). Clinical review: SARS – Lessons in disaster management. *Critical Care*, 9(4), 384–389. https://doi.org/10.1186/cc3041

Heisig, P. (2009). Harmonisation of knowledge management – Comparing 160 KM frameworks around the globe. *Journal of Knowledge Management*, 13(4), 4–31. https://doi.org/10.1108/13673270910971798

Hussinki, H., Kianto, A., Vanhala, M., & Ritala, P. (2017). Assessing the universality of knowledge management practices. *Journal of Knowledge Management*, 21(6), 1596–1621. https://doi.org/10.1108/jkm-09-2016-0394

Inkinen, H. (2016). Review of empirical research on knowledge management practices and firm performance. *Journal of Knowledge Management*, 20(2), 230–257. https://doi.org/10.1108/JKM-09-2015-0336

Jisr, R. E., & Maamari, B. E. (2017). Effectuation: Exploring a third dimension to tacit knowledge. *Knowledge and Process Management*, 24(1), 72–78. https://doi.org/10.1002/kpm.1536

Jørgensen, R., Scarso, E., Edwards, K., & Ipsen, C. (2019). Communities of practice in healthcare: A framework for managing knowledge sharing in operations. *Knowledge and Process Management*, 26(2), 152–162. https://doi.org/10.1002/kpm.1590

Kianto, A., & Andreeva, T. (2014). Knowledge management practices and results in service-oriented versus product-oriented companies. *Knowledge and Process Management*, 21(4), 221–230. https://doi.org/10.1002/kpm.1443

Kianto, A., Ritala, P., Spender, J.-C., & Vanhala, M. (2014). The interaction of intellectual capital assets and knowledge management practices in organizational value creation. *Journal of Intellectual Capital*, 15(3), 362–375. https://doi.org/10.1108/JIC-05-2014-0059

Kim, Y. M., Newby-Bennett, D., & Song, H. J. (2012). Knowledge sharing and institutionalism in the healthcare industry. *Journal of Knowledge Management*, 16(3), 480–494. https://doi.org/10.1108/13673271211238788

Liu, G., Tsui, E., & Kianto, A. (2020). A meta-analysis study on the relationship between strategic KM and firm performance. Paper presented at the 21st European Conference on Knowledge Management, Coventry, UK, 477–483.

Liu, G. (2021). *Towards a deeper understanding of the complex relationships between knowledge management practices and organisational performance: A meta-analytic study* [Doctoral dissertation, Hong Kong Polytechnic University]. PolyU Electronic Theses. https://theses.lib.polyu.edu.hk/handle/200/11457

Liu, G., Tsui, E., & Kianto, A. (2021). Knowledge-friendly organisational culture and performance: A meta-analysis. *Journal of Business Research*, 134, 738–753. https://doi.org/10.1016/j.jbusres.2021.05.048

Liu, G., Tsui, E., & Kianto, A. (2022). Revealing deeper relationships between knowledge management leadership and organisational performance: A meta-analytic study. *Knowledge Management Research & Practice* 20(2), 251–265. https://doi.org/10.1080/14778238.2021.1970492

Martinez-Caro, E., Cegarra-Navarro, J. G., & Solano-Lorente, M. (2013). Understanding patient e-loyalty toward online health care services. *Health Care Management Review*, 38(1), 61–70. https://doi.org/10.1097/HMR.0b013e31824b1c6b

Maier, R., & Remus, U. (2002). Defining process-oriented knowledge management strategies. *Knowledge and Process Management*, 9(2), 103–118. https://doi.org/10.1002/kpm.136

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford University Press.

Raymond, L., Paré, G., & Maillet, É. (2017). IT-based clinical knowledge management in primary healthcare: A conceptual framework. *Knowledge and Process Management*, 24(4), 247–256.

Reinhardt, W., Schmidt, B., Sloep, P., & Drachsler, H. (2011). Knowledge worker roles and actions-results of two empirical studies. *Knowledge and Process Management*, 18(3), 150–174. https://doi.org/10.1002/kpm.378

Shapiro, G., & Markoff, G. (1997). A matter of definition. In C. W. Roberts (Ed.), *Text analysis for the social sciences: Methods for drawing statistical inferences from text and transcripts* (pp. 9–31). Lawrence Erlbaum Associates.

Webster, P. (2020). Canada and COVID-19: Learning from SARS. *The Lancet*, 395(10228), 936–937. https://doi.org/10.1016/s0140-6736(20)30670-x

WHO (2022, May 29). WHO Coronavirus (COVID-19) Dashboard. Retrieved May 29, 2021, from https://covid19.who.int/.

Wu, Y., & Zhao, Y.-M. (2020) Largest group of medics leaves Wuhan for hometowns. Retrieved April 18, 2020 https://www.chinadaily.com.cn/a/202003/31/WS5e82efc8a310128217283586.html.

Xiang, Y.-T., Li, W., Zhang, Q., Jin, Y., Rao, W.-W., Zeng, L.-N., Lok, G. K. I., Chow, I. H. I., Cheung, T., & Hall, B. J. (2020). Timely research papers about COVID-19 in China. *The Lancet*, 395(10225), 684–685. https://doi.org/10.1016/S0140-6736(20)30375-5

Xing, Y. (2020) Science, knowledge essential to prevent spread of outbreak: Expert. Retrieved May 1, 2020, from http://www.chinadaily.com.cn/a/202004/30/WS5eaa9acda310a8b24115302c.html.

Xinhua (2020a). China's COVID-19 cure rate reaches 94% even in hardest-hit place. Retrieved April 18, 2020, from http://en.nhc.gov.cn/2020-04/14/c_79166.htm.

Xinhua. (2020b). *Vice premier stresses treatment, care for every COVID-19 patient in Wuhan*. National Health Commission of the People's Republic of China Retrieved April 24, 2020, from http://en.nhc.gov.cn/2020-04/21/c_79422.htm