

# The Impact of Pandemic-Driven Care Redesign on Hospital Efficiency

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**Purpose:** This study aims to identify medical care transformations during the COVID-19 pandemic and to assess the economic efficiency of these care transformations.

**Methods:** A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviewing and Meta-Analysis (PRISMA) guidelines. The databases used in the search protocol included PubMed, RSCI, and Google Scholar.

**Results:** Ten eligible studies in English and one publication in Russian were identified. In general, the following changes in organization of health care processes since 2020 are observed: hospital at home, telemedicine (physician-to-patient), and the adoption of new information communication technologies within physician-to-physician and physician-to-nurse communication. Earlier trends, such as (a) wider use of electronic devices, (b) adoption of Lean techniques, (c) the incorporation of patient and other customer experience feedback, and (d) the implementation of clinical decision support systems and automation of workflow, tend to be preserved.

**Conclusion:** The most common changes in hospital care organization and the respective impacts of workflow changes (ie, workflow interventions, redesign, and transformations) on the efficiency of hospital care were summarized and avenues for future research and policy implications were discussed. The pandemic demonstrated a need for building more resilient and adaptive healthcare systems, enhancing crisis preparedness along with rapid and effective responses.

**Keywords:** hospital care, care transformation, care redesign, workflow redesign, workflow improvements, efficiency

## Introduction

### Motivation

According to a recent news report,

inefficient clinical workflows in healthcare result in considerable waste. [...] A hospital doctor typically wastes around 45 minutes every day as a result of inefficient communication systems.<sup>1</sup>

In hospitals, examples of these inefficiencies include the duplication of tasks and poor communication among physicians. Such bottleneck inefficiencies have particularly striking effects on patient survival in severe infectious diseases due to their acute clinical course and immediate need for accurate diagnostics and treatment.<sup>2</sup> Health facilities, which manage to optimize their workflows through interventions, increase their return on investment due to the more efficient work of physicians and nurses and improved patient experience. Improvements of patient workflow can be made through, for example, automation, such as having patients use check-in kiosks and/or appointment scheduling and reminders. Other key areas of automation include patient record management, billing and claims processing, prescription management, lab test processing, and hospital inventory management.<sup>3</sup> In general, major strategies for enhancing hospital processes include establishing a real-time communication system, streamlining documentation processes, and tracking patient flow in real-time.<sup>4</sup> Inputs to hospital efficiency, such as environmental setting and access to drinking water,<sup>5</sup> while being assumed across the industrialized Northern Hemisphere remain a core challenge in an array of low and middle-income

countries of the Global South.<sup>6</sup> Certain redesigns were specifically caused by epidemics. For example, during the H1N1 pandemic, hospital care transformations included segregating H1N1 patients, restricting visitors, using personal protective equipment, and modifying prophylactic protocols to mitigate viral transmission risks.<sup>7</sup> Fresh air, sunlight, hygiene standards, and reusable masks at open-air hospitals reduced deaths and infections, suggesting the importance of such measures in hospital care redesign.<sup>8</sup> However, there is limited evidence on economic efficiency of these transformations, especially in the context of the most recent pandemic.

## Research Questions

This study aims to address the following research questions. First: How did medical care transform during the COVID-19 pandemic and which transformations were most common? Second: What was the economic efficiency of these care transformations?

## Defining Key Terms

This review covers the following key concepts. The first concept is ‘healthcare processes’, defined as

the activities that constitute healthcare – including diagnosis, treatment, rehabilitation, prevention, and patient education – usually carried out by professional personnel, but also including other contributions to care, particularly by patients and their families

(Donabedian, 2003, p. 46).<sup>9</sup> In our context, a concept of “care process management” (CPM), which is the use of business process automation and optimization techniques in clinical care in the healthcare environment, is also relevant. CPM helps the subjects of healthcare to change delivery processes. The second concept is “process redesign” (or “process reengineering”), defined as “any methodology that focuses on creating new processes or changing existing ones in major ways”.<sup>10</sup> The purpose of process reengineering consists in improving overall work efficiency through optimizing the process(es) via equipment renewal, material substitution, step simplification, time sequence adjustment, etc. In this review, process redesign is closely related to the concepts of “workflow intervention” and “workflow improvement”. In organization of medical care, this can include, but is not limited to changes in the functions (actions, activities) performed by the subjects (actors, participants) of medical care: doctors, paramedical personnel, other categories of employees of medical organizations; changes in the methods (mechanisms, rules) and intensity of interaction of medical care subjects with each other (doctors with paramedical staff and other workers; general practitioners and narrow specialists, outpatient doctors and hospitals, etc.); changes in the way and frequency of interaction between patients and medical professionals; changes in information flows in the healthcare system. Following the Cochrane-EPOC classification for organizational interventions,<sup>11</sup> interventions were categorized into two groups. First, “changes in structure” include

changes in physical structure, facilities and equipment; changes in the setting/site of service delivery; cooperation with external services or communication and case discussion with offsite health professionals; integration of services; staff organization; clinical multidisciplinary teams; and revision of professional roles / skill mix changes.

Second changes in processes and process management” refer to “changes in process sequences and organization of processes; changes in capacity planning; and presence and organization of quality-monitoring mechanisms.

All other categories represent a combination of the above-mentioned interventions.

Last, but not least, the “economic efficiency” of hospitals is considered as a situation in which nothing can be improved without someone or something else being hurt. Farrell (1957) defined efficiency as

the firm’s success to produce the maximum feasible amount of output from a given amount of input or producing a given amount of output using the minimum level of inputs where both the inputs and the outputs are correctly measured’.<sup>12</sup>

One of the following two concepts is typically used: (1) “allocative” (or “Pareto efficiency”) and (2) “productive efficiency”. Allocative efficiency assumes that any changes made to assist one person cannot be made without harming another. Productive efficiency refers to a situation, in which

no additional output of one good can be obtained without decreasing the output of another good, and production proceeds at the lowest possible average total cost.<sup>13</sup>

The following methods are typically used to measure hospital efficiency: Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), and measures of performance, such as Pabon Lasso's model. DEA is a non-parametric linear programming method used to evaluate the efficiency of decision-making units.<sup>9,10,14</sup> SFA is a parametric method, which calculates the difference between the organization's predicted and actual outputs.<sup>15</sup> Pabon Lasso's model (1986) assesses hospital performance using three indicators: bed occupancy ratio, bed turnover ratio, and average length of stay.<sup>16</sup> These and similar methods to assess hospitals' ability to deliver desired outputs, such as hospital admission episodes, number of prevented mortality cases, and outpatient examinations are widely explored in health economics.<sup>17,18</sup>

## Overview of the Relevant Reviews

General reviews consider redesign strategies and approaches at hospital or industry level within current trends, such as process automation, digitalization, and implementation of computerized clinical decision support systems (CDSS). Elkhuizen et al reviewed the literature on business process redesign in hospital care.<sup>19</sup> Wang et al outlined the avenues of clinical information extraction applications.<sup>20</sup> Shahid et al reviewed applications of artificial neural networks (ANN) in decision-making of healthcare entities.<sup>21</sup> They identified key characteristics and drivers for ANN market uptake to guide their further use in health care. Janssen et al found that the most frequently reported workflow intervention categories referred to anesthetic management, in-hospital patient transfer management, and prehospital management.<sup>22</sup> In their empirical study on improving emergency departments, Pereira et al reviewed previous studies on the application of redesigned heuristics in healthcare.<sup>23</sup> Zayas-Cabán et al synthesized current approaches of workflow automation across industries and prospects of applying workflow automation in healthcare.<sup>24</sup> Eljiz et al provided a scoping review of the empirical studies on the large-scale redevelopment of healthcare facilities as a strategy for the transformation of care systems.<sup>25</sup> Hung et al analyzed three distinct transformational performance improvement approaches, which are commonly used to redesign work processes in medical organizations.<sup>26</sup> Ozkaynak et al introduced relevant theories, principles, and techniques to guide analysis of clinical workflows, methods and processes for workflows improvements, and organizational interventions aimed at workflow redesign.<sup>27</sup>

The second group of studies focus on the quality of care and effectiveness associated with the reviewed organizational changes. Van Leijen-Zeelenberg et al reviewed the impact of care processes redesign on care quality. Their results suggest that process redesign interventions have positive effects on several quality aspects.<sup>28</sup> Buljac-Samardzic et al reviewed interventions that improve team's effectiveness in health care. The following types of interventions were distinguished: (a) "training" (eg, crew resource management, simulation, or general team training); (b) "tools" that "structure, facilitate (through communication technology), or trigger (through monitoring and feedback) teamwork"; (c) "organizational (re)design" is about (re)designing structures to stimulate team processes and team functioning; and (d) "programme", which represents a combination of the previous types.<sup>29</sup> Blakeney et al provided a scoping review of new implementations of interprofessional bedside rounding models aimed at improving teamwork, care, and outcomes in hospitals. Their findings suggest that the majority of the reviewed studies reported positive impacts of IBR implementation across an array of team, patient, and care quality/delivery outcomes.<sup>30</sup> Chowdhury et al analyzed the effect of prehospital workflow optimization on treatment delays and clinical outcomes in acute ischemic stroke. The results of their systematic review and meta-analysis found that prehospital stroke workflow optimizations significantly improved several time metrics related to stroke treatment leading to improvement in intravenous thrombolysis reperfusion rates.<sup>31</sup> Dupuis et al reviewed several effective strategies aimed at reducing waiting times in outpatient rehabilitation services for adults with physical disabilities.<sup>32</sup>

The last group of articles assessed the monetary effects of workflow changes. Evans et al reviewed the empirical studies on how hospitals capture financial benefits of process improvement and the impact of examined redesigns on hospital financial performance.<sup>33</sup> Von Schudnat et al analyzed the economic impact of standardization and digitalization in operating rooms. Only selected standardization methods and introduced digital support systems for intraoperative surgical workflows effectively increased efficiency while maintaining or even improving quality.<sup>34</sup>

Thus, despite having the same or very similar object of the study, these reviews focused on the general or specific issues related to workflow redesigns and their efficiency *without* considering the impact of the COVID-19 pandemic.

## Method

Following the PRISMA reporting guidelines (Page et al),<sup>35</sup> a systematic review was conducted to identify and classify all the literature that is related to our research questions. The databases used in the study included PubMed, RSCI, and Google Scholar. In the search, the following key terms and/or MeSH terms were used: for example, {“redesign” OR “re-engineering” OR “transformation” OR “workflow intervention” OR “process improvement” OR “workflow optimisation”} AND {“care”} AND {“hospital” OR “health facility” OR “medical organization”} AND {“efficiency” OR “effectiveness” OR “efficacy”} AND {“regression” OR “correlation”}. Our search was focused on articles in English and Russian, published between January 2020 and June 2023. For RSCI, Russian synonyms of the key terms were added to account for the nuances of Russian terminology.

## Inclusion and Exclusion Criteria

Publications were included, if they included empirical data; they were peer reviewed; they had extractable data related to hospital or medical care; and they represented “research article” or “original research” type. Publications of the following types were excluded: expert opinion, single-case study, conceptual theoretical study, editorial, commentary, qualitative study, study protocol. Quantitative studies based on either patients’, physicians’, or nurses’ perceptions via survey data, and any studies based on data collected before 2020, were also excluded. The PRISMA diagram demonstrates the details of our search for eligible studies (see Figure 1). Similarly to Elkhuzen et al, process changes could be supported by the introduction or redesign of IT solutions, and there may be organizational restructuring needed for implementing improved process designs.<sup>19</sup>

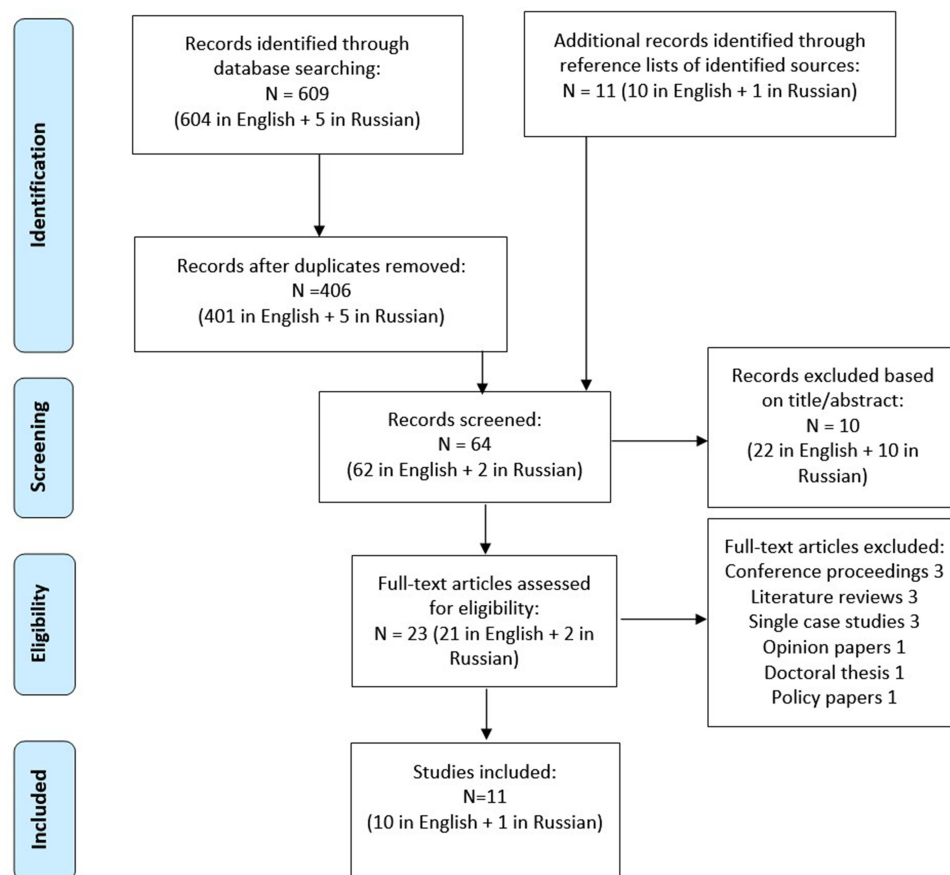


Figure 1 Flow diagram of systematic review.

## Typology of Study Designs

Similar to Shojania and Grimshaw (2005), study designs were assessed according to the following classification: randomized controlled trial, non-randomized control group design, interrupted time series design, controlled before-after design, and before-after design.<sup>36</sup>

## Screening and Quality Appraisal

Retrieved publications were reviewed independently by two researchers (TZ and YT) according to the criteria outlined above, and initial disagreements on the suitability of individual studies were resolved with a third expert (MJ). Reference lists of eligible publications were screened for any further potentially relevant sources.

## Results

The initial search yielded 609 publications after the removal of duplicates. See [Figure 1](#) for details. The selected articles were screened by title and subsequently screened on their abstract or full text. A total of  $N = 11$  studies were selected for review based on the inclusion and exclusion criteria listed above: five from the US; two from China; and one each from Australia, Germany, Spain, and Russia. [Table 1](#) summarizes the articles, which were included in the analysis. The majority of eligible studies (8 out of 11 articles; 73%) used before-after design. The remaining three studies employed interventional study with a control group.

## The Most Common Transformations of Care

Three out of 11 studies (27%), including Rock et al<sup>45</sup> Horn et al<sup>46</sup> and Chen et al<sup>47</sup> considered changes in facilities and equipment. Another three studies (27%), namely, Laurie et al<sup>39</sup> Leupold<sup>40</sup> and Parodi<sup>43</sup> described changes in the setting/site of service delivery. One study (9%) by Lindsay and Lytle (2022) documented changes in process sequences and organization of processes.<sup>41</sup> One study (9%) by Song et al (2020) referred to changes in the physical structure of the care environment.<sup>44</sup> And, one study by Kulikova and Moskvina (2022) documented changes in staff organization.<sup>37</sup> Two other categories represent a combination of the above-mentioned interventions, such as changes in physical structure, changes in facilities and equipment, revision of professional roles/skill mix changes, integration of services.<sup>38,42</sup>

## Economic Efficiency of Care Transformations

In this section, the diverse effects of the reviewed workflow redesigns and transformations are summarized. The studies are grouped by country, starting with the US.

Lindsay and Lytle (2022) report on a successful workflow redesign, which decreased documentation time, redundancy, and click burden for nurses.<sup>41</sup> Specifically, a few segments of nursing documentation were optimized, including the number of visible rows on access to and duplication of information noted elsewhere in the electronic health record (EHR). This redesign resulted in 18.5% decrease time in the EHR; decrease of 7% to 12% of total time in flowsheets; time savings of 1.5 to 6.5 minutes per reassessment per patient; and a decrease of 88% to 97% in number of steps to perform reassessment documentation, ie there is clear evidence of productivity improvement, since time savings could be reallocated to value-added patient care activities.<sup>41</sup> Larsen et al report on workflow improvements in their additive manufacturing lab consisted in the re-design and implementation of the internal project scorecard to standardize evaluation of requests, and the distribution of the responsibility of submission evaluation across lab members. As a result, the time to review new submissions was reduced from an average of 58 days to 4 days, allowing the Lab Manager to devote more time to engineering rather than administrative/decision-making tasks.<sup>42</sup> Parodi et al assessed the impact on readmission rates for CMS (Centers for Medicare and Medicaid Services) core measures (CCM) patients and patients receiving care under the Bundled Payment for Care Improvement (BPCI) Advanced Model resulting from implementing pharmacist-led transitions of care. Pharmacist-driven transitions of care were associated with significant reductions in 30-day CCM and 90-day BPCI hospital readmissions.<sup>43</sup>

Rock et al aimed to reduce unnecessary *Clostridioides difficile* testing implemented computerized clinical decision support (CCDS) systems (hard stop or soft stop) in the EHR. As a result, in nine hospitals implementing hard-stop CCDS and four hospitals implementing soft-stop CCDS, *C. Difficile* testing incidence rate (IR) reduction was 33% and 23%,

**Table I** Summary of Empirical Research on Hospital Care Redesign and Transformation

No	Year, country	Authors, year, link	Intervention Objectives	Study Design	Unit Of Analysis (Project Sample Size), Study Sample Size	Intervention components
1	2022, Russia	Kulikova and Moskvina (2022) <sup>37</sup>	To determine the optimal organizational structure of the ambulance service in Russian regions	Before-and-after study	Ambulance units aggregated by regions	A Unified Dispatch Service was organized in one group of regions, while a complete merger of ambulance units into a single legal entity occurred in another group.
2	2021, Spain	Bernabeu-Wittel et al (2021) <sup>38</sup>	To improve survival, offering humanistic palliative care to residents in their home environment, and reducing hospital referrals	Before-and-after study	Hospital (Nursing home); Before medicalisation program (MP) (n=149) and During MP (n=123)	An informatics infrastructure, medical equipment, and human resources, universal testing, separation of 'clean' and 'contaminated' areas, epidemiological surveys, and unified protocols stratifying for active or palliative care approach were provided.
3	2023, Australia	Laurie et al (2023) <sup>39</sup>	To develop, implement, and evaluate a digital model of maternal and neonatal care	Prospective before-and-after study	A quaternary center; pre-implementation (n=598) and post-implementation (n=337)	Six culturally and linguistically tailored educational videos, home delivery of equipment and prescriptions, and a smartphone app-to-clinician portal for glycaemic review and management were introduced.  'The novel model of care included: (1) initial midwife phone call informing patient of the diagnosis of GDM at 24–28 weeks gestation and on the same day; (2) delivery via email of the link to a GDM education video and registration for use of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) M♡THER app; (3) a Bluetooth capable blood glucose meter was couriered to the patient's home address (at the hospital's expense) along with National Diabetes Support Scheme (NDSS) registration forms, with planned delivery within 48 h of initial phone contact; (4) a face-to-face dual appointment with the CDE midwife and dietitian was scheduled for day seven and day 14 post-diagnosis (attendance rate was 95%), and (5) if required, a face-to-face insulin education appointment was arranged.'

4	2023, Germany	Leupold et al (2023) <sup>40</sup>	The redesign of hypertension management using ICT to improve hypertension control	Interventional study with control group	47 practices and 525 patients (intervention 265; control 260)	<p>Transmission of blood pressure (BP) measurements to a central webspace, etc.</p> <p><i>PIA is a complex intervention comprising two elements: the PIA-ICT (PIA app and PIA-PrMC) and the PIA education (eLearning/ on-site training for practice teams and patients).</i></p> <p><i>The following features characterize the electronic PIA intervention:</i></p> <p><i>1. PIA communication: Highly secure communication between patients (PIA app) and practices (PIA-PrMC):</i></p> <p><i>a. PIA app for patients: transmission of BP measurements, graphic display of BP over time with individual target range, medication plan, ordering of prescription refills, video education and links to BP related information;</i></p> <p><i>b. PIA-PrMC with delegation model: recall and step-wise medication adjustments, predefined and guideline-oriented algorithms for medication regimens, graphic display of BP over time with individual target range, electronic transmission of medication plan to PIA app, predefined process with colour scheme for delegation to PrAs, option to export data from the PIA-PrMC to the EHR for documentation.</i></p> <p><i>2. PIA medication plan transfer: electronic transmission from the EHR to the PIA-PrMC and the PIA app;</i></p> <p><i>3. PIA medication safety: the GP signs each medication plan electronically (required by German law as PrAs have no prescribing privileges);</i></p> <p><i>4. PIA eLearning for GPs and PrAs: videos present evidence-based information on hypertension management including medication classes, how to use the PIA-PrMC and the PIA app, how to obtain valid BP measurements in the practice and at home, and the study details. PrAs complete a short, written exam to qualify as a PIA-PrA.'</i></p>
5	2022, US	Lindsay and Lytle (2022) <sup>41</sup>	To redesign standardized flowsheet documentation workflow	Before-and-after study	Nurses (n=5360)	Standards for usability modifications targeting efficiency, reducing redundancy, and improving workflow navigation were implemented.
6	2022, US	Larsen et al (2022) <sup>42</sup>	To optimize workflow of a hospital's lab operations	Before-and-after study	Hospital; Pre intervention (n = 52); post intervention (n=20)	<p>(1) An existing but underused project submission form was enhanced.</p> <p>(2) An internal project scorecard to standardize the evaluation of requests was designed and implemented.</p> <p>(3) The responsibility of submission evaluation across lab members was distributed.</p>

(Continued)



Table I (Continued).

No	Year, country	Authors, year, link	Intervention Objectives	Study Design	Unit Of Analysis (Project Sample Size), Study Sample Size	Intervention components
7	2022, US	Parodi, Feeley, and Sanchez (2022) <sup>43</sup>	To assess the impact on readmission rates for CMS core measures (CCM) patients and patients receiving care under the Bundled Payment for Care Improvement (BPCI) Advanced Model	Interventional study with control group	Intervention (n=1416 patients), control (n=1203 patients)	A pharmacist-led transitions of care clinic was implemented.
8	2020, China	Song et al (2020) <sup>44</sup>	To evaluate the effect of the optimization of the intravenous infusion workflow in isolation wards for patients with COVID-19	Before-and-after study	30 patients	(1) A special, hygienic medical-order-processing and drug-dispensing area near the isolation area was set up. (2) A medical-order processing to the hygienic area outside of the isolation area was relocated, where nurses do not need to wear a full set of PPE. (3) An intravenous admixture was relocated to the hygienic area outside of the isolation area. Nurses in this area do not need to wear PPE.
9	2022, US	Rock et al (2022) <sup>45</sup>	To reduce unnecessary <i>Clostridioides difficile</i> testing	Before-and-after study	9 academic and 6 community hospitals	Computerized clinical decision support (CCDS) systems (hard stop or soft stop) was implemented in the EHR.
10	2021, US	Horn, Doucette and Sweeney (2021) <sup>46</sup>	To improve the nursing documentation efficiencies and satisfaction of a pediatric admission history workflow	Before-and-after study	Non-profit, free-standing pediatric organization that has outpatient and acute care locations (3347 pediatric admission history forms from 90 days before and 4337 pediatric admission history forms from 90 days after the study intervention; survey with 50 pre-intervention responses and 47 post-intervention responses)	A pediatric essential clinical dataset (ECD) tool was implemented.



11	2020, China	Chen et al (2022) <sup>47</sup>	To shorten door-to-needle time (DNT) at a hospital via multidisciplinary and workflow optimisation in the prehospital, in-hospital, and feedback stages	Interventional study with control group	An 898-bed tertiary hospital; n=128 and n=135 patients receiving treatment in the pre-intervention and post-intervention, respectively	'(1) Engaging the Hospital chief in the study to facilitate improving DNT. (2) Hospital notification via the establishment of a secure web communication platform (ie, WeChat, a Chinese messaging and social app) - hospital providers acquire patient history from family members while at the same time informing patients and their families regarding thrombolysis treatment benefits and risks. (3) Ensuring suspected stroke patients are prioritized for evaluation by an emergency room nurse and physician. (4) Monthly training to stroke and emergency nurses to promptly recognize stroke symptoms and signs, as well as education regarding the therapeutic window for acute stroke patients, by neurologists. (5) Monthly training to emergency room physicians to recognize symptoms and signs of stroke by neurologists. (6) Notifying relevant stroke teams, including emergency healthcare, via a prenotification service before performing head CT scans. (7) Prioritizing CT scan and transfer to radiology. (8) Prioritizing relevant laboratory examination results, especially International Normalized Ratio (INR) for patients prescribed anticoagulants. (9) Facilitating interpretation of head CT by stroke team physicians without requiring formal radiology reports (radiology reports can be given priority in certain circumstances). (10) Training physicians to effectively communicate propositions for thrombolysis with promptly signed informed consent from patients or their families undergoing thrombolysis (family members were allowed to enter the emergency department during the COVID-19 pandemic to sign consent forms). (11) Training nurses to prepare IV rtPA quickly and effectively. (12) Encouraging neurologists to provide immediate feedback if DNT is delayed. (13) Inviting the Hospital chief, along with the staff of neurology, radiology, and emergency departments, to attend monthly stroke meetings to analyze the etiology of DNT-delayed cases. (14) Rewarding associated staff of emergency, neurology, and radiology departments financially if DNT was less than or equal to 60 min. (15) Connecting with the regional Health Bureau and media department of the hospital to raise awareness and public education of acute stroke. (16) Reinforcing standard procedures for acute stroke management after the post-intervention period to achieve a sustainable patient outcome.'
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**Notes:** Intervention types include (1) changes in process sequences or changes in the organization of processes, (2) changes in physical structure, facilities or equipment, (3) revision of professional roles / skill mix changes, (4) change in the setting / site of service delivery, (5) personnel organization, (6) changes incapacity planning, (7) case management, (8) communication and case discussion with off-site health professionals or cooperation with external services, (9) introduction of multidisciplinary teams, (10) introduction of quality-monitoring mechanisms, (11) changes in medical record systems, (12) integration of services or continuity of care programs. All other categories represent combinations of these interventions. Study types included: (1) before-and-after study and (2) interventional study with a control group. An interventional study tests (or tries out) an intervention – a potential drug, medical device, activity, or procedure – in people. It is also commonly referred to as a clinical trial.<sup>48</sup> A distinguishing characteristic of an intervention study is that the intervention (the preventative or therapeutic measure) being tested is allocated by the investigator to a group of two or more study subjects (individuals, households, communities). Subjects are followed prospectively to compare the intervention vs. the control. (standard treatment, no treatment or placebo).<sup>49</sup> A before-and-after study measures differences within a single group before and after an intervention. Unlike a randomized controlled trial, this type of study cannot provide definitive evidence that the intervention caused the differences seen in the study.<sup>50</sup> Originated back in the 1960s, a term “clinical decision support system” (CDSS) is currently defined as a process for enhancing health-related decisions and actions with pertinent, organized clinical knowledge and patient information to improve health and healthcare delivery.<sup>51</sup> A CDSS consists of three elements: (a) data from patients and from their respective environments; (b) algorithm for generating reports out of the data; and (c) reports. A report is a suggestion of further diagnostic examinations, a therapeutic plan to the operators (ie, physicians or nurses) as a suggestion to be considered for their actual diagnostic or therapeutic decision. In addition, a CDSS can incorporate a reiteration process, consisting in further monitoring of the patient, for example, once the therapy has been started to register the patients response to treatment. A new application of algorithms enables further reporting.<sup>52</sup>

respectively. CCDS systems reduced unnecessary *C. Difficile* testing and were perceived positively by healthcare professionals when integrated into their workflow and when displaying relevant patient-specific information needed for decision making.<sup>45</sup> Horn et al implemented a pediatric essential clinical dataset (ECD) tool that positively affected nursing documentation time, dataset completion rate, and satisfaction. In particular, nursing admission history documentation time decreased by 91 seconds and the number of clicks decreased by 38%.<sup>46</sup>

The next group refers to the studies originating in Europe. In their study on digital redesign of hypertension management in Germany, Leupold et al report that the analyzed intervention increased the blood pressure control rate significantly by 23.1% points, while systolic blood pressure decreased by 21.1 mmHg in the intervention group compared to 15.5 mmHg in their control group.<sup>40</sup> Bernabeu-Wittel et al conclude that a coordinated on-site medical program of Spanish nursing homes with COVID-19 outbreaks achieved a higher survival (97% versus 77% before the program) and optimal palliative care rate (84% versus 73% before the program), and a reduction in referrals to hospital (17% versus 29% before the program), thus ensuring rigorous but humanistic and gentle care to residents.<sup>38</sup> Kulikova and Moskvina (2022) studied the work of ambulance services in Russian regions before and after the COVID-19 pandemic and found that in regions of the Central Federal District, where the ambulance service was represented by a single legal entity during the pandemic, excess mortality was lower in comparison with those in the regions where the ambulance service was represented by departments within hospitals. This means a single legal entity has advantages in terms of the quality of healthcare services and the efficiency of the use of financial resources of the institution.<sup>37</sup>

The last group provides the results from Asia and Oceania. According to Song et al, who studied the effect of optimization of the intravenous infusion workflow in isolation wards for patients with COVID-19 in China. The optimization of this workflow included five main steps: establishing the process improvement team, identifying the process steps to be improved, re-optimising the process, implementing the optimized process, and evaluating the new process. It effectively decreased the cost of personal protective equipment and improved the efficiency of infusion and patients' satisfaction. In particular, after the infusion workflow was optimized, average times for preparation drugs and intravenous admixture, and patients' waiting time decreased from 4.84 minutes, 4.03 minutes, and 34.33 minutes to 3.50 minutes, 2.60 minutes, and 30.87 minutes, respectively. Patients' satisfaction increased from 66.7% to 93.3%, and the number and cost of personal protective equipment decreased from 46.67 sets and 186.6 CNY per day to 36.17 sets and 144.6 CNY, respectively.<sup>44</sup> Chen et al conducted a study in China as well, aimed to shorten door-to-needle time via multidisciplinary and workflow optimization in prehospital, in-hospital, and feedback stages. The major implemented changes were a hospital notification system via the establishment of a secure web communication platform, and monthly training to stroke and emergency nurses. The authors report that after the implementation of these changes the median (interquartile range) door-to-needle time decreased significantly from 57.0 (45.3–77.8) to 37.0 (29.0–49.0) minutes. They conclude that the multidisciplinary collaboration and continuous process optimization can result in overall shortened door-to-needle time despite the challenges incurred by the COVID-19 pandemic.<sup>47</sup> Findings by Laurie et al suggest that the analyzed pragmatic service redesign in Australia, which included the implementation of a digital model of care, demonstrates reassuring clinical outcomes in a culturally diverse gestational diabetes mellitus (GDM) cohort. The novel model of care included, for example, (a) initial midwife phone call informing the patient of the diagnosis; (b) delivery via email of a link to a GDM education video and registration for the use of a specialized app; (c) a Bluetooth capable blood glucose meter couriered to the patient's home address; and (d) a scheduled face-to-face appointment with the dietitian.<sup>39</sup>

## Discussion

It seems beneficial to compare our findings with the results of recent studies published after 2019, and based on pre-pandemic data from Australia, Canada, China, the Netherlands, Singapore, Spain, the UK, and the US. For example, Janssen et al assessed the effect of 20 relevant workflow improvement strategies aimed at minimizing the time between onset of ischemic stroke and start of endovascular thrombectomy in the Netherlands.<sup>53</sup> Lai et al compared patients admitted under the integrated general hospital model and patients receiving usual care in public hospitals in Singapore.<sup>54</sup> Luu et al assessed the impact of using an EHR-based messaging system for nonemergent communication between nurses and physicians in US emergency departments.<sup>55</sup> Nether et al assessed implementation of a robust process improvement training program by the hospital neonatal intensive care units in the US.<sup>56</sup> Swedlund et al examined a primary care redesign process aimed at reducing refill requests made outside of office visits in the US.<sup>57</sup> Hung et al examined the

impact of Lean redesign implementation, such as the standardization of exam room equipment and supplies, the streamlining of call management processes, care team co-location, and team management of the electronic inbox, on the amount of time taken for physicians to complete routine clinical tasks in the US.<sup>58</sup> Subbe et al explored the usage of participatory engagement in patient-created and co-designed medical records for emergency admission to the British hospital.<sup>59</sup> Bhayana et al created an electronic list of computed tomography (CT) requests that radiology residents would monitor to optimize after-hours workflow of CT orders.<sup>60</sup> Brooks et al assessed a novel payor-focused strategy to efficiently navigate the prior authorization process while eliminating physician burden and reducing inappropriate denials.<sup>61</sup> Chalwin et al examined the impact of re-design of an existing rapid response system in an Australian metropolitan hospital, including the addition of: (a) regular rapid response team (RRT) meetings (b) RRT role badges, and (c) a structured member-to-user patient care responsibility “hand-off” process.<sup>62</sup> Nguyen et al examined recommended cancer screening rates associated with a US primary care transformation initiative that established team-based care.<sup>63</sup> Mueller et al assessed the initiative to improve advanced notification of inter-hospital transfers in the US. During implementation of the interventions, an advance notification page was sent to the admitting clinicians to minimize inefficiencies caused by poor communication during the transfer of patients between hospitals.<sup>64</sup> Deng et al provided calculations on location optimization for emergency medical service (EMS) facilities in a Chinese megapolis, Chengdu, aiming to optimize the time required for emergency care physicians to reach patients by adding a minimum number of EMS facilities to achieve a given population coverage.<sup>65</sup> Sather et al identified significant improvements in timeliness outcomes driven by application of scripted quality improvement interventions, which included clinical practice guideline dissemination, interhospital transfer (IHT) process redesign, and improvement related to electronic patient arrival notification, electronic imaging exchange, and EHR. The application of scripted quality improvement interventions as part of the IHT process was feasible and effective at improving the timeliness of care and communication of critical information in patients with nontraumatic intracerebral and subarachnoid hemorrhage in the US.<sup>66</sup> Esteban et al, who studied the application of the telemonitoring system in Spain, reported no differences between the intervention group with telemonitoring and the control group (with standard care) in terms of cost-effectiveness, however the intervention program was less expensive than routine clinical practice.<sup>67</sup> In line with the reviewed care transformations, these redesign initiatives were typically associated with increased efficiency and/or workflow improvements.

In low resource settings, four unique health systems adaptations/interventions for restoring, maintaining, and ensuring continuity of care for people living with non-communicable diseases during COVID-19 were identified: telemedicine and teleconsultation strategies, the decentralization of hypertension follow-up services, diabetic retinopathy screening with a handheld smartphone-based retinal camera, and non-communicable diseases medicine drop-off points. The first three redesigns were associated with positive effects.<sup>68</sup>

## Policy Implications and Conclusions

In the observed period, apart from the essential changes in health expenditure and policy,<sup>69</sup> a lot of novel workflow redesigns occurred, which predictably included pandemic-related changes in the physical structures of hospital environments. Other improvements mostly referred to the changes in facilities or equipment, such as implementing a new clinical decision support system, telemonitoring or electronic notification system. The later changes basically are driven by the current trends in and challenges for medical care.<sup>70</sup> Similar to earlier redesigns, each of the examined workflow transformations was associated with improved workflow efficiency and/or improved patient satisfaction. In the long-term, further improvements can potentially be based on hospital workflow optimization via either the more extensive implementation of best practices in workflow innovations or through less known instruments, such as, for example, *k*-means clustering.<sup>71</sup> In addition, policy-makers should ideally consider the roots of healthcare system inefficiencies<sup>72</sup> to build more resilient and adaptive systems, enhancing crisis preparedness along with rapid and effective responses.<sup>73,74</sup>

The COVID-19 pandemic had a significant impact on healthcare systems worldwide, highlighting the need for increased patient and family engagement, enhanced use of health information technologies, a strengthened safety culture, and more reliable medical organizations. Key elements of an improved global pandemic response framework include: (a) data-driven decision making, leveraging robust global disease surveillance and data-sharing; (b) strengthened global public health infrastructure and technology systems; (c) strengthened social protection, equity, and inclusiveness; (d) enhanced international

cooperation and the coordination of policies, resources, and response measures; and (e) ongoing public health education and preparedness efforts at the global level.<sup>73,74</sup> Summing up, pandemic management in a globalized world requires an internationally coordinated public health approach to effectively detect, respond to, and mitigate future pandemics.

The major potential biases of the reviewed studies referred to relatively small sample size,<sup>39,41,43,44,46,47</sup> retrospective<sup>38,42,47</sup> or remote<sup>42,45</sup> data collection, pre-post differences in the baseline characteristics for each sample,<sup>43,46</sup> and the voluntary recruitment of participants.<sup>45</sup> As for additional drawbacks of the examined studies, it is important to note that the absolute majority of the studies (8 out of 11) use a before-and-after design. The findings of before-and-after studies should be treated with caution as they do not have respective control groups by definition.<sup>50</sup> In other words, the results might be different in the contexts of other samples. In some cases, the level of econometrics is low, for example, the use of Pearson correlation in Kulikova and Moskvina,<sup>37</sup> which means it is hard to make conclusions in terms of causality. Second, only the frequencies of redesign measures are observed in the selected papers, but there is no information about which, if any, of the redesign measures are used in practice in different regions and with what frequency. This is an important avenue for future research. Third, most research concerns only staff costs (wasted time, etc), not changes in mortality rates. It is hard to discuss efficiency ignoring the effect of staff costs on the decrease in mortality. Future research should explore this effect. Patient satisfaction, widely used in the examined studies, is a weak criterion for improving the effectiveness of hospital care; it should be supplemented by data on mortality, diagnostic and treatment errors, side effects, and repeated visits. Although there are many avenues for future research, policy implications can be drawn from the results of this review. Firstly, healthcare systems will be more efficient and responsive to potential future epidemics, if hospitals implement relevant changes in their physical structure, such as separating potentially infected patients. Secondly, healthcare facilities will benefit from having high-speed Internet connections to ensure the effective performance of telemedicine. Thirdly, hospital care will benefit from multidisciplinary collaboration and continuous process optimization.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception (YT), study design (YT), execution (YT and TZ), acquisition of data (YT and TZ), analysis and interpretation (MJ, YT and TZ), or in all these areas; took part in drafting (YT and TZ), revising or critically reviewing the article (MJ, YT, and TZ); gave final approval of the version to be published (MJ, YT, and TZ); have agreed on the journal to which the article has been submitted (MJ, YT, and TZ); and agree to be accountable for all aspects of the work (MJ, YT, and TZ).

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