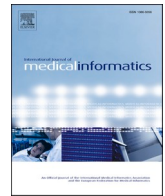




Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Building resilient hospital information technology services through organizational learning: Lessons in CIO leadership during an international systemic crisis in the United States and Abu Dhabi, United Arab Emirates

Karlene Cousins^a, Attila J. Hertelendy^{a,*}, Min Chen^a, Polina Durneva^b, Shangjun Wang^a

^a Department of Information Systems and Business Analytics, College of Business, Florida International University, Miami, FL, USA

^b Department of Business Information and Technology, Fogelman College of Business and Economics, University of Memphis, Memphis, TN, USA

ARTICLE INFO

Keywords:

Ambidextrous leadership
Crisis leadership
COVID-19
CIO
Healthcare IT
IT resilience
IT function resilience
Organizational learning

ABSTRACT

Background: The COVID-19 pandemic was an international systemic crisis which required an unprecedented response to quickly drive the digital transformation of hospitals and health care systems to support high quality health care while adhering to contagion management protocols.

Objective: To identify and assess the best practices during the COVID-19 pandemic by Chief Information Officers (CIOs) about how to build resilient healthcare IT (HIT) to improve pandemic preparedness and response across global settings and to develop recommendations for future pandemics.

Methods: We conducted a qualitative, interview-based study to sample CIOs in hospitals. We interviewed 16 CIOs from hospitals and health systems in the United States and Abu Dhabi, United Arab Emirates. We used in-depth interviews to capture their perspectives of the preparedness of hospitals' information technology departments for the pandemic and how they lead their IT department out of the pandemic.

Results: Results showed that healthcare CIOs were ambidextrous IT leaders who built resilient HIT by rapidly improving existing digital business practices and creating innovative IT solutions. Ambidextrous IT leadership involved exploiting existing IT resources as well as exploring and innovating for continuous growth. IT resiliency focused on four inter-related capabilities: ambidextrous leadership, governance, innovation and learning, and HIT infrastructure.

Conclusions: We propose conceptual frameworks to guide the development of healthcare IT resilience and highlight the importance of organizational learning as an integral component of HIT resiliency.

1. Introduction

The complexity of treating COVID-19 patients and the public health measures needed to combat disease contagion, such as social distancing, masking and hygiene practices required that health informatics leaders such as Chief Information Officers (CIOs) rapidly provide new healthcare information technology (HIT) solutions to their hospitals. It is well known that health CIOs typically face difficulty in justifying a meaningful digital transformation agenda and that healthcare organizations (HOs) have historically been perceived as a late adopter of technological innovations that may be much more commonplace in other industries

[1,2]. But in spite of this conservative approach to digital transformation, the healthcare industry's challenge of meaningful digitization was exacerbated in the face of the COVID-19 pandemic. CIOs not only needed to continue to manage operations, business continuity and information security, but also faced an unprecedented urgency to adapt and innovate to drive business transformation and growth through and beyond the pandemic [3]. Therefore, it is prudent to develop an understanding of healthcare CIO leadership during crisis and the role it plays in digital transformation and HIT resilience. In this qualitative research study, we report on CIOs' best practices which lead to healthcare IT resilience during the COVID-19 pandemic. We highlight the CIOs'

Abbreviations: CIO, Chief Information Officer; CMIO, Chief Medical Information Officer; CDO, Chief Data Officer; CTO, Chief Technology Officers; DOH, Department of Health; EI, Emotional Intelligence; IT, Information Technology; HIE, Health Information Exchange; HIT, Health Information Technology; HHS, Department of Health and Human Services; KPI, Key Performance Indicators; NPS, Net Promoter Score; PPE, Personal Protective Equipment; SLA, Service-Level Agreement; SVP, Senior Vice President; WHO, World Health Organization.

* Corresponding author at: Florida International University, College of Business, Department of Information Systems and Business Analytics, Miami, FL, USA.

E-mail address: ahertele@fiu.edu (A.J. Hertelendy).

<https://doi.org/10.1016/j.ijmedinf.2023.105113>

Received 22 February 2023; Received in revised form 25 May 2023; Accepted 28 May 2023

Available online 2 June 2023

1386-5056/© 2023 Elsevier B.V. All rights reserved.

leadership practices from health systems in the United States (US) and the United Arab Emirates (UAE). To guide the development of HIT resilience, we propose conceptual frameworks which identify the distinctive ambidextrous leadership, governance, HIT infrastructure, and innovation and learning capabilities that play a critical role in responding to a systemic healthcare crisis. Highlights include the importance of organizational learning as an integral component of overall HIT resilience.

2. Background

Preparedness for all types of crises is possible through ambidextrous leadership [4]. Ambidextrous leadership is a proactive approach to simultaneously building organizational capability for operational excellence, with a future orientation for innovation and continuous growth. Ambidextrous IT leaders have the innate ability to strategically build IT capability over time and are focused on exploiting existing IT resources as well as exploring and innovating for continuous growth.

Past research acknowledges the importance of hospital leaders' engagement in both explorative and exploitative efforts, but little is known about the mechanisms that might fuel ambidextrous leadership behavior in hospitals [4] particularly by hospital CIOs and how such behavior contributes to IT resilience. An organization's ability to be resilient involves adapting to overcome an immediate situation of adversity including the development of flexible resources, and the ability to achieve and sustain a learning organization culture [5-7]. Information technology (IT) resilience is manifested as a capability of the system itself such as the information system's ability to anticipate risk and avoid potential losses [5]. However, despite a few exceptions, very few studies on IT resilience account for severe, exogenous shocks such as COVID-19 [5,8,9] and how IT resilience contributes to the resilience of higher-level systems such as HIT functional areas. Therefore, we need better understanding of hospital's institutionalized HIT practices when disasters such as pandemics occur [6].

2.1. Theoretical framework

IT Resilience is possible a priori by sensing and preparing an organization for unknown threats or a posteriori by responding to identified threats [5]. Back-oriented resilience involves the capability to revert to a previous stage [5]. In contrast, forward-oriented actions refer to a proactive way of dynamically responding to a situation including transforming, developing a new identity, or capturing new opportunities [5]. Prior research suggests that organizational learning may be an important element for embedding the knowledge such as that gained from exploration and exploitation into the organization as the organization gains experience in managing the situations they face [10]. Since IT resilience requires the harnessing of knowledge and experience to revert to a previous state or transform to a new identity, organizational learning has implications for HIT resilience during a systemic healthcare crisis such as the COVID-19 pandemic.

We deduce that in order for HIT to be resilient in crises, we need ambidextrous health CIOs who are capable of creating and managing flexible and agile IT resources to address contingencies as the crisis unfolds. Therefore, to conduct a meaningful evaluation of the complex socio-technical processes involved in CIO leadership during the COVID-19 pandemic, we drew on theories of ambidexterity and IT resilience. Ambidextrous leadership was chosen as a theoretical lens because it represented a special approach to leadership that was characterized by the unique crisis context of the COVID-19 pandemic. Ambidextrous leaders simultaneously use explorative and exploitative activities that lead to high performance outcomes [4]. Simultaneously performing routine IT tasks effectively while innovating on the fly to provide new creative IT solutions is known as IT ambidexterity. Gibson and Birkinshaw (2004, p. 209) define ambidextrous organizations as aligned and efficient in their management of today's business demands while also

adaptive enough to changes in the environment that they will still be around tomorrow [11,12]. The foregoing definition points to ambidexterity's exploitative and explorative elements. Exploitation is associated with continuous improvement, efficiency, automation, and stability, while exploration is associated with radical improvement, flexibility, innovation, and agility [13]. Therefore, ambidextrous IT leaders strategically build IT capability over time and in a crisis, should be capable of exploiting existing IT resources as well as exploring and innovating to manage the circumstances the crisis presents.

Table 2 describes the main theoretical concepts in the theoretical framework we applied to this study.

3. Methods

3.1. Study design

We conducted a qualitative, interview-based study of CIOs in hospitals and health systems. We received ethical approval to conduct the study from the Institutional Review Board at the Florida International University.

3.2. Data collection

Using purposive sampling, we recruited 16 CIOs to participate in the study from the American College of Health Care Executives in the US, the Department of Health (DOH) in Abu Dhabi (AD) and from multi-hospital health systems and health information exchange (HIE) organizations. We were able to access respondents from AD due to prior academic relationships between the Florida International University and the DOH. This purposive sampling approach was supplemented by snowball sampling using recommendations from the initial purposive sample [14]. We chose health informatics leaders who possessed knowledge and deep awareness of what was happening in their healthcare organizations during the pandemic. We sought to recruit a representative sample of participants who were most likely to have best practice use cases from diverse health care settings including both rural and urban areas and in two different countries. In the United Arab Emirates digital health was a strategic priority for the Abu Dhabi and Dubai governments prior to COVID-19. Execution of the digital health strategy in Abu Dhabi was a top-down unified approach resulting in all DOH hospitals and medical centers adopting the same HIE. The digital transformation of the health sector was also a priority in the US pre COVID-19 with the passing of the HITECH Act of 2009 (HITECH). HITECH provided health care providers with financial incentives for the meaningful use of certified electronic medical records systems. However, in contrast, the US does not have a unified HIE, with different hospital systems pursuing variable digital health strategies in order to comply with HITECH. Table 1 summarizes the profiles of study participants including CIOs (Chief Information Officers), CTOs (Chief Technology Officers), CDOs (Chief Data Officers), CMIOs (Chief Medical Information Officers), and SVPs (Senior Vice Presidents). Eight (50.5%) participants were in the US. The other eight (50.0%) participants were in the UAE. 12 (75.00%) HOs were in urban areas, defined as a territory encompassing at least 2,500 people [15]. The remaining 4 (25.00%) HOs were located in various urban areas and rural areas (areas encompassing fewer than 2,500 people [15]). All participants were male, possessed graduate degrees with between 5 and 30 years of leadership experience in healthcare. For the rest of the paper, we use CIOs to denote all these health informatics leaders since CIOs constitute the majority of our sample ($n = 12$ or 75.00%).

The interviews were initially informed by the World Health Organization's (WHO's) guidelines for pandemic readiness and information systems governance theory [16,17]. We collected data through remote virtual in-depth interviews with CIOs from November 2020 to May 2021 using Zoom conferencing (Zoom Video Communications) which recorded and automatically produced transcripts of the recordings. We

Table 1
Participant Profiles (N = 16).

Participant ID	Role	Highest Level of Education	Years of Leadership Experience in Healthcare	Location	Urban or Rural or Both
1	CIO	MBA	>30 years	Florida, USA	Urban
2	SVP & CIO	MBA	>20 years	Texas, USA	Both
3	CTO	BS	>20 years	Florida, USA	Both
4	CIO	MHA	>20 years	AD, UAE	Urban
5	CIO	MBA	>20 years	Florida, USA	Urban
6	CIO	MS	>27 years	AD, UAE	Both
7	CIO	MBA	>10 years	AD, UAE	Urban
8	CIO	MS	>5 years	AD, UAE	Urban
9	CIO	MHA	>23 years	Texas, USA	Urban
10	SVP & CIO	MS	>25 years	Massachusetts, USA	Both
11	CIO	MBA	>15 years	AD, UAE	Urban
12	CIO	MS	>15 years	AD, UAE	Urban
13	CMIO	MD/PhD	>14 years	Minnesota, USA	Urban
14	CDO	MD	>10 years	Minnesota, USA	Urban
15	CIO	MBA	>10 years	AD, UAE	Urban
16	SVP of IT & Operation	MBA	>15 years	AD, UAE	Urban

Table 2
Theoretical Concepts.

THEORETICAL CONCEPT	DEFINITION
Exploitation	Alignment: coherence among all patterns of activities within a business unit [12]
Exploration	Adaptability: capacity to reconfigure activities in the business unit quickly [12]
IT Resilience	IT Resilience is possible a priori by sensing and preparing an organization for unknown threats or a posteriori by responding to identified threats [5].
Forward Oriented Actions	Forward-oriented actions refer to a proactive way of dynamically responding to a situation including transforming, developing a new identity, or capturing new opportunities [5].
Backward Oriented Actions	Bouncing back to a previously existing stage and restoring normal oriented operations of its essential structures and functions [5].
Organizational Learning	Organizational learning is a change in the knowledge of an organization that occurs as the organization acquires experience [13].

scheduled interviews with respondents by email who replied and provided informed consent to participate. All five authors participated in the interview process for observation and note taking. Prior to importing the interview transcripts into NVivo for analysis, two research team members checked each transcript against the original recording to ensure the accuracy of the narrative. Each interview took approximately one hour to complete, and all interview transcripts were anonymized. We asked the interviewee’s questions such as the role of HIT in the pandemic, leadership strategies, governance and strategic planning issues, business continuity, COVID-19 applications and innovations developed, assessment of success in addressing the pandemic, and personal leadership challenges. Due to our inductive approach where the abstraction of the interview data to ambidextrous theory occurred post data collection, the interviewees were unaware of the ambidextrous theory that we used to guide the data analysis. This approach minimized researcher bias. The interview guide is included in Appendix 1.

3.3. Data analysis

We performed an inductive concept-driven thematic analysis using NVivo based on the interview guide to code the data [18,19]. In doing so, we adhered to the six key features of an inductive and deductive coding approach, namely (1) developing the codebook with key themes a priori, (2) testing inter-rater reliability, (3) summarizing data and identifying key themes, (4) applying coding templates and new codes, (5) connecting codes and identifying themes, and (6) corroborating and

legitimizing coded themes [18,19]. We used a constant comparative method [20] to examine themes, irregularities, and patterns across interviews.

Initially, all the authors read the transcripts, each generating an initial list of codes based on the semantic content of the transcripts. All the authors collated these into a list of candidate themes and subthemes through consultation with each other. To ensure reliability two research team members coded two interview transcripts independently by using the candidate themes as an a priori coding schema. Additional candidate themes and subthemes emerged during this process. Using Cohen’s Kappa, we calculated the inter-rater reliability for these two interview transcripts [21]. The calculated Cohen’s Kappa value was 0.71, which indicated a substantial agreement between the two research team members. We held reconciliation meetings to discuss and resolve disagreements [21]. There were no significant conceptual differences, and reconciliation primarily focused on refining the labeling of specific subcodes. After the initial round of coding and reconciliation meetings, two research members again coded two other transcripts independently. Cohen’s Kappa was 0.81, indicating substantial agreement and improvement in the collective understanding of major themes and subthemes [21]. The two researchers then coded the remainder of the transcripts. We held a final round of reconciliation meetings to resolve any remaining issues and finalize the codebook. The candidate themes were then grouped to a final set of higher-level categories representing CIO’s ambidextrous leadership practices. These higher-level categories represented strategies to build resilient healthcare IT organizations. Table 3 summarizes the data analysis results.

Table 3
Results of Qualitative Data Analysis.

THEMES	CATEGORIES
Ambidextrous Leadership	Internal & External Environments Assessments Crisis Leadership Emotional Intelligence
Governance	Strategic Partnerships Agile IT Strategy Fast track IT Governance/ IT Governance & Decision Making Regulatory Flexibility
HIT Infrastructure Capability	Secure standard Scalable Modular Infrastructure Telehealth Health information exchange (HIE) Business Analytics and AI Secure IT Infrastructure
Innovation and Learning	Diverse IT Team Innovation and Learning Culture Measure and Monitor Resilience

4. Results

During the pandemic, effective hospital CIOs exhibited ambidextrous leadership behavior and were able to both exploit and explore so as to provide the IT resources the business needed to provide quality healthcare. In the following sections, we outline the ambidextrous CIO's leadership practices used to build HIT capabilities to contribute to HIT resilience and crisis readiness. Table 3 summarizes our findings and places these practices into four categories: ambidextrous leadership, governance, IT infrastructure, and innovation and learning capabilities.

4.1. Ambidextrous leadership

As the crisis unfolded, ambidextrous CIO leadership were required to assess the internal and external healthcare environment to understand how to respond to the crisis effectively and exercise crisis leadership and emotional intelligence capabilities.

4.1.1. Internal & external environments assessments

In addition to ensuring routine business operations, CIOs need to be able to constantly scan the external healthcare environment to understand the challenges, anticipate change, adapt and innovate to ensure their healthcare businesses grow and remain profitable. Though HOs had IT business continuity plans they were unprepared for handling the pandemic's unique challenges. Several key challenges emerged including moving to remote work locations; providing patients with virtual care; protecting IT employees; sourcing IT resources; managing surge demand and capacities; information sharing and safeguarding the information assets and maintaining business continuity. To address these challenges, ambidextrous CIOs engaged in explorative and exploitative leadership practices.

"We've achieved as much as we can with the traditional processes. We need to get to the next level using technology. Innovation will help us to get there." [Hospital 10].

4.1.2. Crisis leadership

CIOs were expected to exercise effective crisis management capabilities to prepare for the occurrence of unexpected crisis, deal with the salient implications of crisis, and grow from the disruptive experience of crises. However, emergency preparedness training, tabletop and live exercises improved the crisis response but did not sufficiently prepare CIOs to handle the unique needs of the COVID-19 pandemic. Thus, CIOs had to evolve crisis management skills to handle the pandemic as well as typical crisis such as man-made disasters (cyberattacks, system failures and terrorism), natural disasters (hurricanes and earthquakes), atypical crises and multiple types of crises simultaneously [22,23]. Critical were reviews to determine what went well and potential improvements to learn and grow from the crisis.

"How do we – support testing right like how are we getting testing sites up and running? And then that evolved into how do we send workers home –, so that people can telecommute and then that evolved into how do we work from home? And then that evolved into how do we defend our healthcare infrastructure against an eminent cyber-attack." [Hospital 5].

4.2. Emotional intelligence

Emotional intelligence (EI) is the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use the information to guide a person's thinking and actions. CIOs exercised emotional intelligence to navigate the challenging COVID-19 environment. Though EI was recognized as a useful leadership tool pre-pandemic, clinical professionals' exhaustion level and mental health due to long hours of work and isolation from families and friends brought EI to the forefront of CIO's leadership practices. CIOs implemented flexible work hours, mandatory day-offs, virtual happy hours and mental health hotlines. Staff were encouraged to empathize with

others and help team members when they could. Compassion and empathy promoted teamwork, better worker satisfaction, and reduced emotional exhaustion. CIO's EI persisted post pandemic.

"After a couple weeks we learned —just kind of pick your head up and you just realize that people are putting 80–90 h a week. And so, at that point, I started implementing mandatory two days off—we would disconnect your account if I felt that you were working on your two days off." [Hospital 1].

4.3. Governance

During the pandemic, rigid governance and strategic planning processes were restricted the ability to move quickly. HOs shifted to agile strategic planning, fast tracked governance processes and relied on strategic partnerships and regulatory flexibility to exploit existing IT resources and to innovate.

4.3.1. Strategic partnerships

Historically, the CIO role was plagued with ambiguity primarily attributed to the polarized views of the C-Suite about the role of technology in organizations. The polarized views ranged from believing that IT is an administrative expense, to considering IT a significant strategic opportunity. However, COVID-19 emphasized HIT's critical role in providing quality health care through cross-unit and cross-functional business-IT collaborations (e.g., creating testing facilities, housing COVID-19 patients, among others). CIOs' partnerships with clinicians provided the HIT teams with actionable insights into understanding clinicians' needs and ways of helping clinicians deliver high quality health care. Trust and transparency were the critical components of building such partnerships. On the one hand, to build trust at the executive level, the executive and management teams needed to trust that the IT teams *"were checking all of those boxes connecting with the folks that they need to connect with."* [Hospital 10] On the other hand, successful execution of the COVID-19 IT projects increased visibility and dependability of the IT department as a department that can respond to crises and *"innovate – and take the business into new areas."* [Hospital 12].

4.3.2. Agile IT strategy

The COVID-19 pandemic disrupted HOs forcing them to accelerate their digital transformation road maps. This provided an opportunity to leverage analytical competency (e.g., software, artificial intelligence, human expertise) to provide better patient care. CIOs stressed the importance of being adaptable to the changing environment. One CIO described the current circumstance of technology road mapping as the *"future crashing down on the present."* CIOs had to be increasingly agile and make decisions on the fly, whether acquiring new HIT or refining existing HIT to respond to information needs and support the business. To be adaptable, CIOs introduced minimally viable HIT solutions and refined them over time by adding more functionality.

4.4. Fast-track IT governance & decision-making processes

HOs had formal IT governance to provide a structure for to ensure that HIT investments support business objectives. Though guided by formal IT Governance frameworks such as COBIT, IT innovation, decision making and investments are typically slow, process driven and conservative. Moving quickly to respond to the crisis required the implementation of new IT governance capabilities, committee structures, processes, and designated funding for COVID-19 HIT initiatives. This included a fast lane approval process and structure that ran alongside pre-existing decision-making processes and structures. This resulted in an agile and faster IT leadership and decision framework being activated during the pandemic.

"We did not — bypass so much of the best practices – but we fast tracked in some ways so–, things move faster." [Hospital 7].

4.4.1. Regulatory flexibility

The U.S. DOH and Human Services (HHS) approved the use of telehealth services as part of the Coronavirus Preparedness and Response Supplemental Act. Telehealth services were billed at the same rate as in-person medical services. HIPAA exemptions for providers enabled Facetime or Skype as a means to communicate with patients. A key regulatory obstacle that previously inhibited the delivery of telehealth was the need for providers to have separate state licenses for the areas they served. Recognition of out of state licenses enabled providers to provide telehealth services nationally. The HHS implemented COVID-19 exemptions to waive potential HIPAA penalties for good faith use of telehealth during the pandemic. In response CIOs were able to quickly scale and expand the provision of telehealth services.

“For things like telehealth consultation, HIPAA enforcement was being set aside. So, we did allow physicians to interact with patients without using HIPAA compliant tools.” [Hospital 3].

The AD (DOH) is the sole regulator of healthcare services in the Emirates. It too relaxed certain regulatory requirements, while enforcing public health measures to protect the population. The AD DOH issued its initial telemedicine regulatory framework in 2014. In September 2020, the AD DOH issued an updated DOH Standard on Tele-Medicine (‘DOH Telemedicine Standard’), bringing AD’s telemedicine standards in line with U.S. federal legislation, and care delivery models. These AD DOH waivers permitted telemedicine services to operate with limited restrictions including specialized services such as psychotherapy and the DOH Remote Care Platform for virtual care visits.

5. Hit infrastructure capability

Standard, scalable and modular IT infrastructure provided the capability to quickly, build and deploy new applications to meet the pandemic’s needs. Critical infrastructural components included telehealth, HIE, business analytics and AI and HIT security.

5.1. Scalable, standard and modular IT infrastructure

CIOs spoke of two approaches to building HIT infrastructure. The first approach involved building modular vendor agnostic platforms in-house. Instead of relying on a single vendor’s suite of information technology products, this approach involved selecting the best applications to meet the user’s requirements and interweaving them into a cohesive platform. In the second approach CIOs depend on a single IT vendor as a true partner who could be relied on to prioritize the HOs needs to scale up and expand IT services in moments of crisis. Both approaches support agility and scalability in terms quickly increasing stakeholders’ access to critical applications. Solution reuse, prototyping and innovation and a combination of cloud computing, health information exchange, electronic health records (EHR), analytics and mobility capabilities facilitated quick COVID-19 solutions which became a permanent part of the IT infrastructure.

“We definitely designed the IT infrastructure for flexibility, to be able to grow it and change it on demand, essentially, and for resiliency.” [Hospital 3].

5.2. Telehealth

HOs limited in-person visits because of social distancing requirements. Therefore, HOs rapidly transitioned to telehealth, virtual visits and remote health care monitoring. This required increasing telehealth user capacity to accommodate additional users and replicate the in-person hospital visit virtually while ensuring patient satisfaction and quality of care. These new health care modalities persisted post-pandemic.

“We were already planning to launch Telehealth as part of our digital front door strategy that we’d been working on for the better part of the last two years and so having already layered in the foundational elements for the

digital front door, having already started the project for Telehealth for us it was really a matter of just accelerating that and moving that across the line.” [Hospital 15].

5.3. Health information exchange

Hospitals that did not have access to HIE either built ad hoc partnerships or developed work arounds to facilitate data sharing. These included daily or twice daily batch updates of COVID-19 test results or participation in health information networks such as the Common Well Health Alliance, which allows disparate IT systems and venues to share health data.

In contrast to the bottom-up approach in the U.S. where HOs took the initiative to implement HIE, the UAE adopted a top-down approach to HIE adoption. In January 2019, the AD DOH launched Malaffi, the Middle East region’s first HIE platform. As the pandemic progressed, by October 2021, all public and private health care facilities including 59 hospitals, 1,100 clinics and medical centers and 380 pharmacies were connected to Malaffi.

Whether in the U.S. or AD, CIOs invested in connections to government-funded and private hospitals and the development and integration of web and mobile applications and patient portals into the healthcare infrastructure to improve access to patient information and greater integration with EHRs, mobile applications, and COVID-19 vaccination scheduling and administration.

“It will be more easy for the clinician because now all the Abu Dhabi hospitals are connected — So at the time of pandemic, only the government sectors was connected. Now the private sector is also enrolled. And now they are launching the patient portal also.” [Hospital 6].

5.4. Business analytics and artificial intelligence

Business analytics infrastructure (predictive, prescriptive, diagnostic, and descriptive analytics, and data visualization tools) and artificial intelligence such as machine learning helped HOs to understand information about the initial outbreak and predicted surges. This enhanced HOs capability to respond to COVID-19 resource shortages such as IT equipment, personal protective equipment (PPE), tests, beds, supplies, vaccines and people. Providing clinical informatics and data analysis dashboards for tracking and reporting COVID-19 infection cases and lab results were critical for clinicians to access on their desktop and mobile devices at the point of care. HOs that implemented enterprise data warehouses and data marts pre-pandemic could expand their analytical competencies to incorporate mobility and social media data to facilitate predictive and forecasting modeling.

“We have our business analytics tool to be able to integrate COVID aspects into the financial impact, activity impact – activity of the physicians, activity of the departments, etc. So, yes, there was an effort to be able to isolate these COVID data to be able to draw graphs and reports.” [Hospital 11].

5.5. Secure IT infrastructure

The pandemic emphasized the importance of secure and integrated healthcare infrastructure, security programs and policies and strategies for responding to phishing, cyber and ransomware attacks. Implementing zero-trust initiatives helped to prevent data breaches by defining a protected surface within the HIT infrastructure and eliminating the concept of trust from an organization’s network architecture, using tools such as multi-factor authentication, identity and access management, identity protection and next generation endpoint security technology. Zero-trust required all users to be authenticated, authorized, and continuously validated for security configuration and posture, before being granted access to applications and data.

“When the cyber threat became eminent, – it was one of the times when IT had to just take the reins. – IT said, look, here’s the deal. —You can’t access

your personal email on the network any longer, right, you're going to have a different configuration. —You probably know of this shadow IT departments —. Can't do that anymore. Sorry. Anything that sits on our networks now belongs to IT.” [Hospital 5].

Although many HOs participated in disaster drills and tabletop exercises pre-pandemic, business continuity plans, though useful, did not adequately address the pandemic's complexities. However, increased cybersecurity training and cyber vigilance and the use of serious games and red teams where hackers are employed to detect and evaluate security vulnerabilities and enabled hospitals to defend their systems against intrusion attempts.

6. Innovation and learning

Three important aspects of innovation and learning during the pandemic included a diverse IT team, an innovation and learning culture and measurement and monitoring of HIT resilience.

6.1. Diverse IT team

A diverse IT team gives enables HOs to respond to crises in general. Pre-pandemic, some CIOs designed the “21st century IT team”, focusing on diversity, equity, and state-of-the-art IT skills to promote agility. This structure involved functional areas such as DevOps, CloudOps, Identity and Access Management, Clinical Informatics, Enterprise Architecture, AI and Data Science and Finance. CIOs invested in IT staff's professional development and education in agile methods and process improvement and built cross-functional teams to increase communication and coordination across the organization. A diverse agile and flexible team that can work with partners such as clinicians to create multi-disciplinary teams can quickly assess the organization's needs for new technology, engage in problem solving and identification of IT solutions and the rapid delivery of IT services that were not previously contemplated to respond to different types of crises.

“We were empowered by the city's public health to do contact tracing on behalf of the City. So, we immediately leapt into contact tracing game. Now we have a fantastic epidemiology team along with a number of our other faculty and clinicians and myself got together to really design a contact tracing system, top to bottom. Because it wasn't just contact tracing. We were also doing —, home monitoring for patients.” [Hospital 9].

6.2. Innovation and learning culture

Most HOs are late adopters of HIT innovations due to complex regulations, scarce financial resources and change resistance. Pre-pandemic, some hospital CIOs were able to overcome innovation barriers and had innovation centers in place with sandboxes of prototypes and experiments which were quickly translated into full-scale implementations as COVID-19 advanced. Innovations were developed in collaboration with external partners who funded development through innovative business models involving royalties, licensing fees and grants. Others took advantage of the pandemic to introduce innovation processes and develop fast minimally viable products and improvement iterations for digital solutions such as testing, telehealth, follow-up and vaccination management.

Some CIOs dedicated time for innovation using the Gartner Run Grow and Transform Model where 75% of an employee's time is dedicated to run the business, 20% to grow the business and 5 % to transform or innovate. Other CIOs did not have innovations centers within their functional area but fostered community-driven innovation. HOs developed non-COVID-19 specific innovations (e.g., telemedicine, remote patient monitoring, cloud computing, digital front door, and medication adherence) and more specific COVID-19 related innovations (e.g., contact tracing, 3D printed masks, virtual hospital visits and COVID-19 data modeling). HOs learned that IT innovation could take place rapidly and collaboratively without increasing risk to patients or adversely affecting

quality of care.

“The one thing – IT can do, is 3D print. So why don't we 3D print ventilators and N95 masks? I have no idea what it takes to go into an N95 mask. – But boy, did I know that we have some of the best biologists in the country —. I know we have some of the best infection prevention faculty in the country. And we have a whole school of people around public health. I said, Okay. Let's grab these guys let's grab our surgeons and our clinicians and let's grab our – engineering school and let's 3D print N95 masks.” [Hospital 9].

As the pandemic progressed CIOs recognized the need to reflect and learn from the pandemic and to prepare them for further crisis and to build resilience.

“Comparing to the when the pandemic started and today, I'm definitely, we're better prepared. –There was a lot of learning as we go. And we can duplicate these learnings if it's for COVID-19, we can do it for any other infectious disease.” [Hospital 4].

6.3. Measure and monitor HIT resilience

Before the pandemic, many CIOs had not measured HIT resilience and success in terms of the response to a pervasive, long term exogenous shock such as the COVID-19 pandemic. Traditional IT success measures focus on clinical quality and operational efficiency. However, the pandemic has made IT success much more complex to measure. Evidence of success and resilience included how the healthcare IT performed with respect to formal key performance indicators (KPIs), informal indicators and anecdotal evidence. CIOs defined success during the pandemic based on successfully and securely transitioning the HO to remote work and virtual care. CIOs mentioned anecdotal evidence from the various stakeholders (e.g., the physician community, the DOH, patients and employees) that the HIT department has been the anchor and MVP (most valuable player) of the COVID response. [Hospital 14].

“I don't have any formal KPIs that I can just pull out and share with you. But the way I divided up in my mind is, did we help the organization successfully transition to in person to remote work on most things? Yes, the quality of experience could be better, but on most things, yes. Did we transition our clinical delivery services to a significant asynchronous and daily medicine? Again, yes, with some caps on quality instability. Did we prevent ourselves from getting hacked or being taken for ransomware? The answer is yes, but we came very close, I know that for sure. And did we not overspend our budget? So, the answer is yes, the one metric where I would say we failed and I don't see how we could have not failed is just keeping our employees, healthy and happy. That's a— human price that I think every organization has paid, unfortunately.” [Hospital 14].

7. Discussion

7.1. Implications for HIT resilience

We contribute to the literature by providing a comprehensive approach to building HIT resilience for improved crisis response. As shown in Fig. 1, we demonstrate that HIT resilience involves several interrelated capabilities including ambidextrous leadership, governance, HIT infrastructure and innovation and learning. While prior research has acknowledged the individual importance of these capabilities for organizational performance [24-27], we demonstrate that they are essential for effective health care crisis response when working in tandem.

Although previous research has examined the exploitative and explorative aspects of ambidextrous leadership, we emphasize the role of ambidextrous leadership in crisis management. For CIOs managing HIT in a crisis, emotional intelligence and crisis management are important leadership skills needed to exploit existing IT resources, innovate and to manage the people element. In particular, there is strong evidence that leaders' EI is an important predictor in improving employees' work effectiveness, job satisfaction [28-30] and organizational commitment resulting in employees who provide better quality of care.

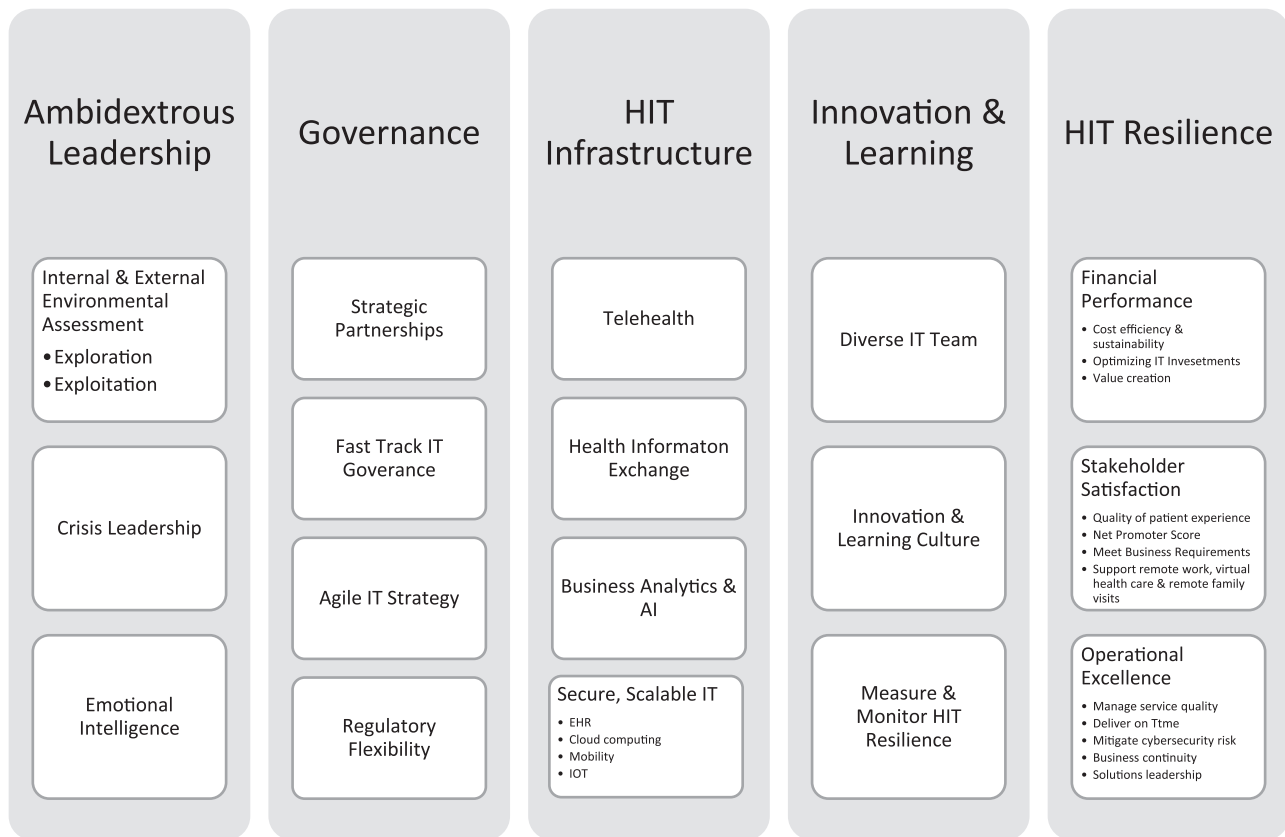


Fig. 1. HIT Resilience Framework.

Hence, leaders' EI during a crisis is an important requirement for employees' wellbeing, psychological empowerment and quality of care. Metrics such as employees' perceived empowerment and satisfaction, the staff turnover rate and work performance can measure the success of EI practices.

Traditionally, IT Governance and strategic planning are rigid and highly structured and controlled processes [31,32]. Our findings show that accelerating the rhythm and urgency of IT governance decision making, investments and strategic plans during a crisis can result in HIT resilience. HOs should plan for accelerated plans and governance processes during a crisis. Resources and structures should be designed to enable swift decision-making in a crisis. We also highlight the role of regulatory flexibility in promoting HIT innovations and new forms of health care services during a crisis and building resilience, an area where there is limited existing research [33,34].

We also show that innovation and learning are crucial components for managing healthcare crisis. While innovation is recognized as a key success factor in various industries, it remains a novel concept for many hospital CIOs [27,35-37]. Health organizations can foster an innovation culture by establishing innovation centers, rewarding innovation, and continuously challenging their workforce to generate new solutions tailored to their specific needs, through regular experimentation and the development of minimally viable products in a sandbox environment. Building a diverse IT team prior to a crisis is essential; however, in the aftermath of a crisis, when healthcare worker shortages and burnout are prevalent, CIOs must prioritize employee retention and recruitment to secure the necessary talent. Workforce diversity is vital at all organizational levels, with diversity in leadership roles particularly effective in attracting tech talent. Special attention should be given to reducing the attrition rate for women in technology, as it is more than double the rate for men [38].

The results suggest that some HOs successfully developed forward-oriented HIT resilience. Indicators of forward-oriented HIT resilience

were assessed through financial performance, stakeholder satisfaction and operational excellence. To build HIT resilience, the HIT function must evolve from being a cost-focused service provider to a partner in lowering health care costs and increasing business value creation, in alignment with the HO's strategy. To achieve operational excellence, HOs can focus on the on-time delivery of services, uptime, delivering 24/7 service without interruption, responding to incidents and new requests within service-level agreements' (SLAs) targets, and launching projects within time and budget constraints. Essential components for high service quality and operational excellence include cloud services, mitigating cybersecurity risk, business continuity planning, analytics capability, secure, mobile and scalable IT infrastructure and location independent IT services for remote work and virtual care. HOs can monitor stakeholder satisfaction by evaluating changes in the patient experience using measures such as the patients' Net Promoter Score (NPS) or service satisfaction surveys, with non-conventional metrics including the capability to support a mobile and remote workforce, enabling swift adaptation to new ways of working and providing virtual care for patients.

7.2. Implications for organizational learning

When severe, long term exogenous shocks to the HO occurs, organizational learning is an important mechanism for embedding the outcomes of exploitative and explorative IT leadership practices into organization to foster IT resilience. Exploitative IT leadership practices build upon existing knowledge, refined through past organizational learning, to address the crisis. In contrast, explorative IT leadership practices create new innovative structures, processes, policies, technology infrastructure and innovations to tackle the crisis, leading to new experiences, knowledge and opportunities for organizational learning.

IT Resilience can be achieved either a priori, by sensing and preparing an organization for unknown threats, or a posteriori, by

responding to identified threats [5]. As mentioned previously, firms can adopt either backward or forward oriented actions to address external threats [5]. Most of the CIOs we interviewed did not aim to revert their HIT to its pre-COVID-19 stage. Instead, they embraced the long-term adoption of the forward-oriented actions identified in our findings, integrating them into HO's strategic and operational business models.

While HO's have experienced short term IT crisis such as a cyber-attack or systems failure, previous research has not explored the factors promoting continued IT resilience during and after a long term, severe, exogenous shock to the HO at an international level such as the COVID-19 pandemic. Our findings suggest that forward-oriented IT resilience can be facilitated through organizational learning during such a crisis, focusing on leveraging existing IT capabilities through exploitative practices and integrating new processes, structures, and policies arising from explorative practices.

Our results reveal that during the COVID-19 pandemic, organizational learning manifested as an ongoing cycle wherein the outcomes of the dual facets of CIO leadership – exploitation and exploration, were transformed into knowledge. This knowledge, in turn, reshaped the organization's health information technology environment, influencing future practices and experiences. Most CIOs interviewed had graduate degrees and substantial healthcare leadership experience. While the CIOs acknowledged the absence of a specific guiding framework for their pandemic response, their backgrounds and the subsequent ambidextrous leadership approaches adopted during the pandemic displayed similarities. These similarities in leadership approaches during the pandemic seemed to leverage fundamental IT governance, incident response, strategic management and leadership competencies. Given these CIOs academic qualifications and professional experiences, the possession and effective utilization of these competencies align well with established expectations within the field. As described by the interviewed CIOs, the lessons learned and outcomes of the exploitative and explorative ambidextrous IT leadership practices became embedded in the HO's active context [13], including members, tools, tasks and networks, through interactions with the new HIT and processes implemented during the crisis. However, the latent context [13], comprising the organization's culture, must also adapt to embrace innovation, agility, speed and emotional intelligence. Therefore, the ability to learn and adapt is critical to the resilience, performance, and long-term success of organizations.

Overall, the results show that organizational learning is considered both an important precondition for HIT resilience which relies on past learning and an outcome of it that promotes future learning. Therefore, HIT resilience and organizational learning may be codependent and reinforce each other [39]. Table 4 summarizes our theoretical findings.

8. Strengths and limitations

We offer valuable insights and make significant contributions to the existing literature on HIT resilience and the role of CIOs during extreme situations. One of the key strengths of this study is its examination of CIO leadership in two different countries (U.S. and AD), providing a comparative perspective that enriches our understanding of the challenges and opportunities faced by CIOs in diverse health care settings. Additionally, the study proposes a holistic framework that combines the findings from both countries, offering future researchers a comprehensive approach to explore HIT resilience and CIO leadership. Furthermore, by highlighting best practices in large health care systems with adequate resources, the research serves as a valuable guide for other organizations seeking to improve their own HIT resilience and the effectiveness of their CIO leadership. Nevertheless, our study is not without its limitations. The cross-sectional nature of the research design restricts its ability to capture the evolution of CIO leadership and HIT resilience over time. Future research should consider employing longitudinal designs to provide a more comprehensive understanding of these phenomena. Moreover, the sample's focus on relatively large healthcare

Table 4
Theoretical Implications for Organizational Learning & HIT Resilience.

Exploitation	Exploration	Implications for organizational learning & hit resilience.
AMBIDEXTROUS LEADERSHIP CAPABILITY		
Internal & External		
Environmental Assessments		
Traditional approaches used to address results of internal and external assessments activated.	Traditional approaches & business continuity plans insufficient for addressing COVID-19's unique challenges steering HO's towards technology innovation.	CIO's learn that crisis response must make room for (1) innovation; (2) providing HIT to accommodate the rapid relocation, mobility and provision of health care services under social distancing requirements; and (3) unexpected results of an internal and external assessment of the crisis.
Crisis Leadership		
Emergency preparedness training, business continuity plans, table top and live exercises improve the crisis response to the pandemic but are inadequate.	Crisis leadership expands to manage a pandemic's unexpected and unique requirements in particular social distancing, Technology and social distancing requirements bring CIOs into the incident command system to provide an integrated response.	Supplementing prior IT crisis leadership capabilities with organizational learning about how to leverage HIT to manage a pandemic contributes to forward oriented IT resilience.
Emotional Intelligence (EI)		
EI recognized as a useful leadership & motivational tool but inconsistently used in past practice.	EI becomes critical for recognizing mental health issues, managing employees' mental health, isolation, motivation & job satisfaction. CIOs implemented remote work, flexible work hours, mandatory days-off, virtual happy hours & mental health hotlines.	CIOs learned to become more aware & empathetic. CIOs embraced a people focused leadership approach. EI initiatives are formalized & maintained post pandemic to assure a resilient IT workforce.
INNOVATION & LEARNING CULTURE		
Diverse IT Team		
Diverse (gender, race, IT skills) IT teams developed pre-pandemic to deliver HIT.	Diverse team quickly assesses the organization's needs for new technology, engages in problem solving & identification of IT solutions & the rapid delivery of new, innovative IT services.	Continued hiring, retaining, motivating & training diverse teams result in an agile & nimble IT workforce positioned for problem solving & innovation & the ability to deliver quick solutions leading to forward oriented IT resilience. Multi-disciplinary teams learned to work together & across silos (e.g., clinicians with IT) which strengthens strategic partnerships & builds resiliency.
Innovation Culture		
Innovation centers/	Existing innovation	Continued

(continued on next page)

Table 4 (continued)

Exploitation	Exploration	Implications for organizational learning & hit resilience.
communities with sandboxes of prototypes and experiments are quickly translated into full-scale implementations. Improvement iterations for digital solutions such as testing, telehealth, vaccinations.	culture supports development of fast minimally viable products including non-COVID-19 (e.g., telemedicine, remote patient monitoring, cloud computing, digital front door, & medication adherence) & COVID-19 innovations (e.g., contact tracing, 3D printed masks, virtual hospital visits, COVID-19 data modeling).	experimentation and innovation post-pandemic contribute to new experiences, knowledge and organizational learning & forward oriented IT resilience.
IT INFRASTRUCTURE CAPABILITY		
Scalable, Standard and Modular IT Infrastructure		
Scalable and modular infrastructure provided either through vendor agnostic inhouse solution or reliance on single vendor facilitated expansion to accommodate the demands of new applications and users.	Solution reuse, prototyping, cloud computing, health information exchange, analytics and mobility capabilities facilitated quick new innovative COVID-19 solutions and scalability to accommodate surge in cases.	Designing flexible IT infrastructure with the ability to quickly integrate new tools and applications and manage the surge of users, enables the adaptation of HIT to future crises and builds resiliency. New COVID-19 IT solutions accompanied with new business processes to provide virtual care and telehealth are permanently embedded in HOs beyond the pandemic.
GOVERNANCE CAPABILITY		
Strategic Partnerships		
The business considers IT either as an administrative expense, or as a significant strategic opportunity.	IT's critical role in providing quality health care through cross-unit & cross-functional business-IT collaborations is leveraged.	Successful execution of the COVID-19 IT projects demonstrates that the IT department is a strategic business partner that can respond to crises & innovate to take the business into new areas.
Regulatory Flexibility		
Regulations provide strict guidelines for EHR & HIE adoption and use, and patient privacy and security of patient data.	Taking advantage of the COVID-19 regulatory exemptions for telehealth & recognition of out of state licenses drive telehealth innovations and virtual care.	HOs learn that regulatory flexibility supports agility, innovation & quality of care during crisis.
IT Governance & Decision Making		
IT Governance frameworks such as COBIT to facilitate sound decision making on health IT investments.	A new fast track IT governance process shortens approval process & facilitates quick investments in COVID-19 health IT.	HOs learn that IT governance flexibility supports quick IT decision making and investments during crisis. It is possible to implement HIT quickly to improve quality of care and save lives.
Agile IT Strategy		

Table 4 (continued)

Exploitation	Exploration	Implications for organizational learning & hit resilience.
Accelerated pre-existing technology roadmaps & strategies.	Digital transformation included becoming more agile, moving faster & making decisions on the fly.	HOs learn that HIT strategic plan horizons can be shortened & innovations quickly delivered without harming patients.

systems which were well resourced which limits the generalizability of the findings, as the unique challenges and resource constraints faced by CIOs in smaller organizations are not addressed. Finally, despite our best efforts, we could not recruit any female CIOs to participate in our study. Future research can continue to explore the interplay of gender dynamics and diversity, along with their influence on organizational culture and leadership styles, to provide a more nuanced understanding of HIT resilience and CIO performance during crises.

9. Conclusions

We proposed conceptual frameworks to guide the development of healthcare IT resilience and highlight the importance of organizational learning as an integral component of HIT resiliency. We showed that healthcare CIOs were ambidextrous IT leaders who built resilient HIT by rapidly improving existing digital business practices and creating innovative IT solutions. Ambidextrous IT leadership involved exploiting existing IT resources as well as exploring and innovating for continuous growth. IT resiliency focused on four inter-related capabilities: ambidextrous leadership, governance, innovation and learning, and HIT infrastructure. To build HIT resilience, healthcare CIOs should continue to shift to being more experimental and innovative, developing sandboxes of new ways to use IT to provide patient care bearing in mind the clinician's realization that the patient does not have to be in front of the caregiver to receive high quality patient care. Though it may be tempting to return to the pre-pandemic mindset, this is an important time of reflection for healthcare CIOs on what they learned during the pandemic. Lastly, due to the financial exigency brought on by the pandemic, HOs may be pressured to return strategic investments in information technology to the background. We caution that the decision to forgo the opportunity to continue the digitization of healthcare services would have a devastating impact on HIT resilience.

Summary points

What We Already Know on the Topic	What This Study Added to Our Knowledge
<ul style="list-style-type: none"> The COVID-19 pandemic was a systemic international crisis which forced and accelerated digital transformation in many healthcare organizations, presenting challenges to their HIT. Very little empirical evidence is available about the nature of successful health care CIO leadership practices during a systemic crisis such as a pandemic or how to build HIT resilience. There is evidence that hospital leaders may engage in ambidextrous practices, but little is known about how these practices develop and unfold. 	<ul style="list-style-type: none"> Provided valuable lessons on how healthcare CIO leadership capabilities lead to HIT resilience during an international systemic crisis. Identified the common and inter-related elements comprising resilient HIT across two international healthcare domains; Abu Dhabi and the USA. Provided evidence of how HIT infrastructure including HIE implementations improved HIT resiliency. Provided evidence of healthcare CIO's exploitative and explorative ambidextrous leadership practices during crisis management. Suggests how ambidextrous CIO leadership and organizational learning contribute to forward HIT resilience. Provides a holistic framework for HIT leaders to build and measure HIT resilience and prepare for future crisis.

10. Author contribution statement

Karlene Cousins, Min Chen and Attila Hertelendy contributed to the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting and critically revising the article for important intellectual content, and approving the final article.

Polina Durneva and Shangjun Wang contributed to the acquisition of data, analysis and interpretation of data, and the drafting of the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements:

We would like to acknowledge Dr. Hamed Al-Hashemi, Strategic Advisor for the DOH AD and Lina Shadid, Healthcare Lead for PWC Middle East for their assistance with coordinating interviews and their insights with the healthcare systems in AD.

Appendix A. Interview guide

1. Was your IT Department ready for COVID-19? Explain how?
2. Indicate the role of IT in the following:
3. Did you know what your role was during the COVID-19 pandemic?
4. What was the role of leadership to support IT efforts?
5. How did IT governance play a role/ change?
6. Did you have an IT Business Continuity Plan that was integrated throughout the Hospital? Did it help with COVID-19 efforts?
7. How has health IT's role changed as a result of the COVID-19 pandemic?
8. Does the Health IT support the telemedicine infrastructure? (Skip this question if already answered in J)
9. Has the Health IT department developed new applications, or innovations during the COVID19 crisis?
10. Outline the challenges the Health IT department had during the COVID19 period (Open ended)
11. What type of training did your Health IT have specific to COVID19 response and planning.
12. Did your Health IT dept engage in any simulation or live preparedness exercise to simulate a transition to Telemedicine or a disaster?
13. What measures have been taken to ensure the security of remote workers i.e., Cybersecurity provisions and patient information and the IT infrastructure.
14. Were the Health IT successful in the COVID19 response and what are the KPI 's for success?
15. What were the issues with compliance? HIPAA, Compliance Reporting, Regulatory Waivers?
16. What has changed from March 2020 (Onset of Pandemic) until now 2nd wave of Pandemic?
17. Were there any Cybersecurity breaches, hacks or significant intrusion attempts.
18. Please describe your personal experience as a CIO leader.
19. In your opinion what leadership attributes should future CIO leaders have?
20. What are the strengths and areas of improvement for the 2nd wave of Covid or future disasters / emergencies?

References

- [1] R. Kohli, S. Johnson, Digital transformation in latecomer industries: CIO and CEO leadership lessons from Encana Oil & Gas (USA) Inc, *MIS Q. Exec.* 10 (4) (2011).
- [2] N. Fabian, Digital transformation and organizational implications, *Inf. Syst. Syst.* 22 (3) (2022) 191–224.
- [3] C.V. Laur, P. Agarwal, G. Mukerji, et al., Building Health Services in a Rapidly Changing Landscape: Lessons in Adaptive Leadership and Pivots in a COVID-19 Remote Monitoring Program, *J. Med. Internet Res.* 23 (1) (2021) e25507.
- [4] E. Foglia, L. Ferrario, E. Lettieri, et al., What drives hospital wards' ambidexterity: Insights on the determinants of exploration and exploitation, *Health Policy* 123 (12) (2019).
- [5] R.J. Floetgen, J. Strauss, J. Weking, et al., Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19, *Eur. J. Inf. Syst.* 30 (3) (2021).
- [6] H.M. Ali, J. Ranse, A. Roiko, C. Desha, Investigating Organizational Learning and Adaptations for Improved Disaster Response Towards "Resilient Hospitals": An Integrative Literature Review, *Prehosp. Disaster Med.* 37 (5) (2022) 665–673.
- [7] I. Dierickx, K. Cool, Asset Stock Accumulation and Sustainability of Competitive Advantage, *Manag. Sci.* 35 (12) (1989) 1415–1524.
- [8] M. Sakurai, H. Chughtai, Resilience against crises: COVID-19 and lessons from natural disasters, *Eur. J. Inf. Syst.* 29 (5) (2020) 585–594.
- [9] M. Sakurai, J. Kokuryo, Design of a Resilient Information System for Disaster Response. *International Conference on Information Systems* 2014.
- [10] L. Argote, E. Miron-Spektor, Organizational Learning: From Experience to Knowledge, *Organ. Sci.* 22 (5) (2011) 1123–1137.
- [11] C.B. Gibson, J. Birkinshaw, The Antecedents, Consequences, and Mediating Role of Organizational Ambidexterity, *Acad. Manag. J.* 47 (2) (2004) 209–226.
- [12] J.G. March, Exploration and exploitation in organizational learning, *Organ. Sci.* 2 (1) (1991) 71–87.
- [13] K. Werder, C. Uo, C.S. Heckmann, et al., Ambidexterity in Information Systems Research: Overview of Conceptualizations, Antecedents, and Outcomes, *J. Inform. Technol. Theory Appl.* 20 (1) (2019) 2.
- [14] C. Parker, S. Scott, A. Geddes, Snowball sampling. *SAGE research methods foundations* (2019).
- [15] 2010 Census Urban and Rural Classification and Urban Area Criteria. US Census Bureau 2010. <https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural/2010-urban-rural.html> (accessed in January 2022).
- [16] Pandemic Influenza Preparedness and Response. World Health Organization 2009.
- [17] P.P. Tallon, R.V. Ramirez, J.E. Short, The Information Artifact in IT Governance: Toward a Theory of Information Governance, *J. Manag. Inf. Syst.* 30 (3) (2014) 141–178.
- [18] L.S. Nowell, J.M. Norris, D.E. White, et al., Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative, Methods* (2017).
- [19] V. Braun, V. Clarke, Using thematic analysis in psychology, *Qual. Res. Psychol.* 3 (2) (2006) 77–101.
- [20] B.G. Glaser, The Constant Comparative Method of Qualitative Analysis, *Soc. Probl.* 12 (4) (1965).
- [21] M.L. McHugh, Interrater reliability: the kappa statistic, *Biochem. Med. (Zagreb)* (2012) 276–282.
- [22] Y.L. Bavi, B. Shao, A. Newman, et al., Crisis leadership: A review and future research agenda, *Leadersh. Q.* 32 (6) (2021) 101518.
- [23] A.J. Hertelendy, E. McNulty, C. Mitchell, J. Gutberg, W. Lassar, P. Durneva, D. Rapp, Crisis leadership: The new imperative for MBA curricula, *The Int. J. Manag. Educ.* 19 (3) (2021) 100534.
- [24] L. Wang, Y. Sun, J. Li, Y. Xu, M. Chen, X. Zhu, D. Wang, Effects of Ambidextrous Leadership on Employees' Work Behavior: The Mediating Role of Psychological Empowerment, *Front. Psychol.* 13 (2022).
- [25] K.P. Wasdani, A. Vijaygopal, M.J. Manimala, A.K. Verghese, Impact of corporate governance on organisational performance of Indian firms, *Indian J. Corporate Governance* 14 (2) (2021) 180–208.
- [26] C.H. Chen, Y.L. Lan, W.P. Yang, F.M. Hsu, C.L. Lin, H.C. Chen, Exploring the Impact of a Telehealth Care System on Organizational Capabilities and Organizational Performance from a Resource-Based Perspective, *Int. J. Environ. Res. Public Health* 16 (20) (2019) 3988.
- [27] D. Jiménez-Jiménez, R. Sanz-Valle, Innovation, organizational learning, and performance, *J. Bus. Res.* 64 (4) (2011) 408–417.
- [28] S.A. Udod, K. Hammond-Collins, M. Jenkins, Dynamics of Emotional Intelligence and Empowerment, Perspectives of Middle Managers *SAGE Open* (2020).
- [29] S. Fernandez, T. Moldogaziev, Employee Empowerment, Employee Attitudes, and Performance: Testing a Causal Model, *Public Adm. Rev.* 73 (3) (2013) 490–506.
- [30] L. Karimi, S.G. Leggat, T. Bartram, et al., Emotional intelligence: predictor of employees' wellbeing, quality of patient care, and psychological empowerment, *BMC Psychology* 9 (1) (2021) 1–7.
- [31] A. Prasad, P. Green, J. Heales, On IT governance structures and their effectiveness in collaborative organizational structures, *Int. J. Account. Inf. Syst.* 13 (3) (2012) 199–220.
- [32] A.A. Kaissi, J.W. Begun, Strategic planning processes and hospital financial performance, *J. Healthc. Manag.* 53 (3) (2008) 197–208.
- [33] A. Lal, H.C. Ashworth, S. Dada, L. Hoemeke, E. Tambo, Optimizing pandemic preparedness and response through health information systems: lessons learned from Ebola to COVID-19, *Disaster Med. Public Health Prep.* 16 (1) (2022) 333–340.
- [34] L. Pecchia, D. Piaggio, A. Maccaro, C. Formisano, E. Iadanza, The inadequacy of regulatory frameworks in time of crisis and in low-resource settings: personal protective equipment and COVID-19, *Heal. Technol.* 10 (6) (2020) 1375–1383.

- [35] M.M. Migdadi, Organizational learning capability, innovation and organizational performance, *Eur. J. Innov. Manag.* (2019).
- [36] S. Flessa, C. Huebner, Innovations in health care—a conceptual framework, *Int. J. Environ. Res. Public Health* 18 (19) (2021) 10026.
- [37] B. Siwicki, CIOs tackle barriers to innovation, telehealth integration, analytics and more, *Healthcare IT News*. (2021). <https://www.healthcareitnews.com/news/cios-tackle-barriers-innovation-telehealth-integration-analytics-and-more>.
- [38] C. Ashcraft, B. McLain, E. Eger, Women in Tech: The Facts, National Center for Women & Information Technology, 2016. <https://ncwit.org/resource/thefacts/> accessed November 2021.
- [39] T.J. Vogus, K.M. Sutcliffe, Organizational resilience: towards a theory and research agenda, in: 2007 IEEE international conference on systems, man and cybernetics 2007, 3418–3422.