IMPLEMENTATION OF DIGITAL CONTACT TRACING FOR COVID-19 IN A HOSPITAL CONTEXT: EXPERIENCES AND PERSPECTIVES OF LEADERS AND HEALTHCARE WORKERS

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Thesis submitted to the University of Ottawa
in partial Fulfillment of the requirements for the
Master of Science in Health Systems

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Abstract

Background. In parallel with public health responses, health systems have had to rapidly implement infection control strategies during the SARS-CoV-2 (COVID-19) pandemic. Various technologies, such as digital contact tracing (DCT), have been implemented to enhance case investigations among healthcare workers' (HCWs). Currently, little attention has focused on the perspectives of those who have implemented DCT innovations and those who have adopted such technologies within a healthcare environment.

Objective. This study aimed to describe the implementation, acceptance, and outcomes of a web-based DCT tool used extensively at a specialized pediatric acute-care hospital in Ontario during the COVID-19 pandemic from the perspective of key stakeholders.

Methods. Using an exploratory qualitative design, this research involved 21 semi-structured interviews with healthcare administrators (n=6; 29%), occupational health specialists (n=8; 38%), and healthcare workers (n=7; 33/%) at the Children's Hospital of Eastern Ontario. Interview protocols and analysis were guided by the RE-AIM (Reach, Effectiveness, Adoption, Implementation, and Maintenance) framework. The interviews lasted on average 33.6 minutes in length and were audio-recorded. Verbatim transcripts were subjected to thematic analysis using NVivo software.

Results. The implementation of DCT during the COVID-19 pandemic was viable and well-received among stakeholders. End-users cited that their engagement with the DCT tool was facilitated by its perceived ease of use and the ability to gain awareness of probable COVID-19 exposures; however, risk-assessment consequences and access concerns were present as barriers (*reach*). Stakeholders commonly agreed that the DCT tool exerted a positive outcome on the hospital's capacity to meet the demands of COVID-19, notably through the facilitation of timely case investigations and by informing decision-making processes (*effectiveness*). Implementors and occupational specialists conveyed staffing impacts, and the loss of nuanced information as unintended consequences (*effectiveness*). Safety-focused communication strategies and having a technology that was human-centered were crucial factors driving staff *adoption*. Conversely, *adoption* was challenged by the misaligned delivery of the DCT tool with HCWs standard practices, alongside the evolving perspectives of COVID-19. Some end-users expressed an initial disconnect towards the DCT tool, raising questions about the fidelity of the implementation. However, stakeholders collectively agreed on the viability of the DCT approach and its applicability to infectious disease practices (*maintenance*).

Conclusion. Stakeholders reported DCT in the hospital context to be acceptable and efficient in meeting the demands of the COVID-19 pandemic. Recommendations for optimized DCT use include education and training for relevant personnel, improved access and usability, and integration into clinical systems. The findings contribute to evidence-based practices and guide future scale-up initiatives focused on digital surveillance in the hospital context.

Acknowledgements

I extend my heartfelt gratitude to my thesis supervisor, Dr. Mirou Jaana, for guiding me through the thesis journey. Your guidance, support, and leadership has helped me grow intellectually, academically, and professionally. It has truly been an honor to work under your supervision.

A sincere thank you to the members of my thesis committee, Dr. Jennifer Ellis, Dr. Samia Chreim, and Dr. Charles Hui, for generously sharing your expertise, unwavering support, and insightful feedback. This project owes much of its completion to your commitment to this research.

To the study participants, I am appreciative of your time and sincerely thank you for openly sharing your experiences of contact tracing and the COVID-19 pandemic with me.

Finally, to my friends and family who have been an exceptional support system throughout this journey – your love and support has served as my pillars of strength over the last two years. To my parents, you have taught me the value of hard work, always reminded me of my capabilities, and never failed to brighten my days with encouragement and positivity.

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List of Acronyms

SARS-CoV-2	COVID-19
Non-pharmaceutical Interventions	NPI
World Health Organization	WHO
Public Health Agency of Canada	PHAC
Digital Contact Tracing	DCT
Healthcare Workers	HCW
Health Human Resources	HHR
Children's Hospital of Eastern Ontario	CHEO
Research Electronic Data Capture	REDCap
Public Health Ontario	PHO
Centers for Disease Control and Prevention	CDC
Case Management Tool	CMT
Medical Monitoring Tool	MMT
Proximity Tracking Tool	PTT
Electronic Medical Record	EMR
Closed-Circuit Television	CCTV
Radio Frequency Identification	RFID
Personal Protective Equipment	PPE
Ontario Ministry of Health and Long-Term Care	MOHLTC
Radio Frequency Identification	RFID
Reach, Effectiveness, Adoption, Implementation and Maintenance	RE-AIM
COVID-19 Safety Team	CST
Infection Protection and Control	IPAC
Respiratory Syncytial Virus	RSV

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Introduction

The infectious disease SARS-CoV-2 (COVID-19), initially identified in December 2019, emerged as the most consequential health crisis in the last century (Aleem et al., 2022). Nonpharmaceutical interventions (NPI), also known as public health measures, have been widely introduced to reduce the transmission rates of COVID-19 by preventing the introduction of disease, controlling the spread of disease, and reducing the burden on health systems (Desvars-Larrive et al., 2020). NPIs have been implemented to decrease the spread of transmission, protect those most at risk of severe outcomes, reduce the total number of deaths and decrease the demand on healthcare systems (Ludwig et al., 2020). Although considerable efforts in clinical research have led to advanced knowledge and the development of vaccines for COVID-19, the virus and novel variants have had devasting impacts and severe consequences on a global scale (Cascella et al., 2022; Public Health Agency of Canada, 2020).

Contact tracing has been recommended by public health authorities such as the World Health Organization (WHO) and the Public Health Agency of Canada (PHAC) as an essential containment strategy to prevent COVID-19 transmission (PHAC, 2021; WHO, 2021). Contact tracing can be defined as the "process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission" (WHO, 2021, p.1). Before the COVID-19 pandemic, contact tracing was typically conducted through traditional approaches, such as telephone calls or in-person interviews (Anglemyer et al., 2020; Thomas Craig et al., 2021). During the pandemic, it became readily apparent that such traditional approaches for identifying cases of COVID-19 and managing contacts who had been exposed to the virus demanded an extensive allocation of time and resources. In response to this challenge, there has been a shift toward the implementation of technology to support a more efficient process of contact tracing (Anglemyer et al., 2020). However, the focus of digital contact tracing (DCT) has primarily been directed to community settings, with limited translation into healthcare environments (Tang et al., 2021).

Given the inherent close contact in healthcare environments and the infectious nature of COVID-19, contact tracing has been shown to protect high-risk patients, ensure the safety of healthcare workers (HCW), and reduce the number of new cases in the hospital setting (Bechmann & Geginat, 2022; Ho et al., 2020; La Torre et al., 2021; Schneider et al., 2021; Stuart

et al., 2020). Furthermore, the health human resources (HHR) and time requirements per case needed to conduct traditional contact tracing within complex healthcare environments have been recognized to be impractical for COVID-19 (Breeher et al., 2020; Ho et al., 2020; Zirbes et al., 2021). In the literature, contact tracing approaches in hospitals have predominantly been presented as traditional, digital, or a combination of both. While studies describing the use of DCTs, either autonomously or in combination with traditional approaches, have highlighted the role of technology in supporting the scalability of contact tracing processes during COVID-19, they have remained limited in scope. As a result, critical aspects regarding DCT performance and adoption within real-world hospital contexts remain largely unexplored (Chambers & Anglemyer, 2022).

Since the emergence of the COVID-19 virus, Canadian hospitals have been faced with various challenges and threats to the delivery of health services (Canadian Institute for Health Information, 2021). It has been estimated that from the onset of the pandemic to the spring of 2022, over 50,000 adult patients and 4000 pediatric patients across Canada were hospitalized with COVID-19 (Mitchell et al., 2023), which demonstrates the magnitude of additional pressures placed on our healthcare systems. Although contact tracing has held significant importance in preventing infections within healthcare environments, its application in the Canadian healthcare context is not well documented. Nonetheless, the PHAC (2022) has suggested that understanding the experiences and insights of HCWs concerning infection control strategies taken within their workplace during COVID-19 is imperative to inform future decision-making. Therefore, exploring the various perspectives related to the implementation of DCTs in the hospital context has important implications for future pandemic planning.

Children's Hospital of Eastern Ontario Digital Contact Tracing

In response to the pandemic, the Children's Hospital of Eastern Ontario (CHEO) implemented a digitally enabled contact tracing tool to aid in COVID-19 case and contact management among HCWs. This DCT tool was constructed using the Research Electronic Data Capture (REDCap) platform. REDCap is a highly secure and Health Insurance Portability and Accountability Act-compliant instrument typically used to capture data in the clinical research field (Patridge & Bardyn, 2018). Using this platform, CHEO has created two surveys for case and contact management. This includes an epidemiological survey with validated measures to

assess the risk of staff COVID-19 exposure and provide guidance and a survey for COVID-19-positive staff. Further details on the CHEO's approach to contact tracing are provided in the Methodology section.

Statement of Problem

Currently, the literature on DCT in hospitals has primarily been conducted in various countries around the globe, with few reports detailing how such efforts have been tailored to meet the challenges of the pandemic in the Canadian context. This finding has important implications, as adequate contact tracing has been identified as a core response to Canada's response to COVID-19 (Bhatia et al., 2020). Furthermore, as mentioned above, the PHAC has stated that the experiences of HCWs regarding infection control strategies taken within their workplace are imperative to inform future decision-making (PHAC, 2022).

In the community context, researchers have indicated that considering the unique context of DCTs, explorative and qualitative inquiries are needed to further understand users' perspectives on such technologies (Zetterholm et al., 2021). However, little attention has focused on the views of those who have implemented and used DCTs in healthcare environments. Given the relatively recent use of DCT in the hospital context, an exploratory approach is appropriate to foster a more comprehensive understanding of its utilization in this setting, its impacts, and the challenges faced with the implementation of such technologies. Moreover, with a lack of a widely accepted definition of DCT effectiveness in hospitals, it is imperative to give the perspective of various stakeholders who have been directly involved in using and implementing this technology-based approach for contact tracing.

Last, it has been noted that Ontario requires additional research to better understand how healthcare environments can adopt and implement infection prevention and practices (Moore, 2023). Reports have also detailed the important role of developing crisis management plans, including infectious disease prevention, preparedness, and recovery strategies for future infectious diseases of concern (Abdi et al., 2022). Therefore, it has been recognized that developing infection control responses within healthcare environments will remain a persistent priority during the post-pandemic response (Moore, 2023; Yang et al., 2020). Collectively, this highlights that the lessons learned from the COVID-19 pandemic can be utilized to help health systems further develop pandemic preparedness and future infectious disease response plans.

Research Questions and Objectives

Despite the potential benefits of DCTs, the extent of their implementation, adoption, and outcomes within the hospital context during the COVID-19 pandemic remains limited. Therefore, I aimed to understand the perspectives of various hospital stakeholders regarding the execution of a DCT tool using an exploratory qualitative, interview-based study. Specifically, this research was based on the following question:

> *What are the perspectives of healthcare leaders and healthcare workers on digital contact tracing adoption, implementation, and outcomes during the COVID-19 pandemic?*

I addressed this research question by (1) identifying the factors that facilitated or challenged the success of DCTs within this context during the pandemic, (2) highlighting variations in perspectives across key hospital stakeholder groups concerning the outcomes and impacts of the DCT tool at both the individual and organizational levels, (3) offering recommendations for future improvements aimed at increasing DCT impact and uptake among HCWs, and (4) providing benchmarking evidence that can serve as a foundation for informing DCT efforts in future pandemic response plans.

Literature Review

Contact During the COVID-19 Pandemic

Overview and Characteristics

The WHO defines contact tracing as "the process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission" (WHO, 2021). Contact tracing begins with identifying the index case (WHO, 2021). Public Health Ontario (PHO) describes an index case as the source of infection or the first case reported to public health authorities (PHO, 2021b). During the identification process, the index case is asked about their activities and whom they have been in close contact with two to three days before symptom onset (Anglemyer et al., 2020; Asiimwe et al., 2021). However, the definition of close contact is context specific, as it varies between diseases and settings (Anglemyer et al., 2020). During COVID-19, the definition of close contact has continuously been revised throughout the

pandemic. Next, contact tracing entails determining the individuals who have been in close contact with the index case. This step allows public health authorities to inform individuals of their exposure and provide guidance on quarantine protocols, symptom management and support during their isolation period (WHO, 2021). The final stage consists of regular follow-up on symptom monitoring and testing outcomes, in which contacts are guided on how to best protect their health (Asiimwe et al., 2021; Ruebush et al., 2021). Ultimately, the primary functions of contact tracing are to locate high-risk contacts, identify active cases before widespread transmission and provide preventative management in traced contacts (Tian et al., 2013).

When applied systematically, contact tracing has the potential to break the transmission chains of infectious diseases (Katehakis et al., 2020). However, it is noteworthy that contact tracing can be utilized in all phases of infectious disease outbreaks (Schneider et al., 2021). First, contact tracing can serve as a crucial preventive measure at the onset of an infection by halting widespread transmission. However, during periods of infection waves, contact tracing can help to identify and isolate the necessary contacts. Second, when infections decline, contact tracing can be used to manage resurfacing and periodic outbreaks. For these reasons, the implications of contact tracing are expected to manifest at the individual level and population levels, and from a medical standpoint (Müller & Kretzschmar, 2021). At the individual level, contact tracing allows possibly exposed individuals to be identified early, isolated, and obtain the necessary medical direction and guidance (Müller & Kretzschmar, 2021). At the population level, contact tracing can limit the spread of infection by breaking the chain of transmission (Müller & Kretzschmar, 2021). At the medical and scientific level, contact tracing facilitates ongoing analysis and interpretation of health surveillance information. For instance, this can include examining different transmission modes, risk factors, and the average time for one infected person to infect another, which are crucial for developing infection control measures (Müller & Kretzschmar, 2021). However, the ability of contact tracing to reduce disease transmission is reliant on the timely detection and prompt isolation of index cases (Braithwaite et al., 2020).

Historically, by locating high-risk contacts and identifying and managing cases before infection occurs, contact tracing has become an integral part of many infectious disease control programs (Tian et al., 2013). It has been successfully used to disrupt the chain of transmission in various infectious diseases and epidemics, such as smallpox, Ebola, polio, human immunodeficiency virus, sexually transmitted diseases, tuberculosis, avian influenza, measles,

severe acute respiratory infections and Middle East Respiratory Syndrome (Armbruster & Brandeau, 2007; Hegde & Masthi, 2020; Piret & Boivin, 2021; Ramsay et al., 2019; Tian et al., 2013). Traditionally, contact tracing has primarily been a manual practice, requiring in-person or telephone interviews for case identification, contact listing, and follow-up protocols (Asiimwe et al., 2021).

While contact tracing is not a novel approach for mitigating the spread of infectious diseases, the global scale and urgency required by the COVID-19 pandemic have demonstrated significant challenges in this area. The following sections identify some of the challenges faced in contact tracing during the pandemic.

Challenges with Contact Tracing

Despite the current progress in pandemic control, research and reports have indicated the various challenges of contact tracing. During the peak of the Omicron wave, PHO epidemiological reports identified that high confirmed case counts and positive tests were indicative of Ontario experiencing a sixth pandemic wave of COVID-19 (Public Health Ontario, 2022). As the Omicron variant increased transmissibility, the Centre for Disease Control and Prevention (CDC) encouraged continuing to build the level of vaccination nationwide and maintaining prevention strategies to halt COVID-19 transmission (CDC, 2021).

During COVID-19, it has been essential for contact tracing to promptly identify individuals and advise quarantine among contacts before infection occurs (Braithwaite et al., 2020). For this reason, a quick and comprehensive contact tracing system has been recommended to best mitigate COVID-19 transmission (Braithwaite et al., 2020). However, contact tracing systems have continuously been overwhelmed and challenged by the demand of the pandemic (O'Connell & O'Keeffe, 2021). Consequently, contact tracing has often been initiated once the progression of infection has occurred, making it difficult to disrupt transmission (Schneider et al., 2021). As a result, there has been an urgent need to augment the scale and speed of contact tracing to best identify individuals who have been exposed to the disease (O'Connell & O'Keeffe, 2021).

A significant area of concern in the literature concerns the extensive resources needed to conduct traditional contact tracing (Anglemyer et al., 2020; Kretzschmar et al., 2020; Ruebush et al., 2021). For example, a study conducted in New Zealand indicated that a team of three to five

public health officials required two to three days to complete contact tracing for an individual COVID-19 case (Verrall, 2020). This has been similarly experienced in Canada, as there has been a lack of human resources to efficiently carry out large-scale contact tracing (PHAC, 2021). Moreover, if delays occur in notifying individuals of their exposure to the virus, this is likely to disrupt the effectiveness of contact tracing (Anglemyer et al., 2020; Kleinman & Merkel, 2020). As traditional approaches to contact tracing tend to be slow, laborious, and inefficient, public health authorities have also been challenged to meet all the requirements due to recall biases (Anglemyer et al., 2020; Grekousis & Liu, 2021; Kretzschmar et al., 2020; O'Connell & O'Keeffe, 2021).

A recent systematic review exploring the organizational aspects of contact tracing, defined as the models adopted to support contact tracing implementation during the COVID-19 pandemic, highlighted the limited availability or relevant literature within this area (Amicosante et al., 2023). By exploring contact tracing approaches implemented across various target settings, including the general population, HCWs and healthcare environments, occupational settings, vulnerable populations, and travelers. Amicosante et al. (2023) also revealed that the focus of studies exploring contact tracing efforts during COVID-19 has primarily focused on proxy data and thus remains limited in scope. The authors concluded this to be a result of the difficulties related to obtaining and measuring the effectiveness of different contact tracing approaches. For example, several ethical concerns exist related to randomly assigning or withholding individuals from contact tracing interventions, as it is an established safety mitigation (Amicosante et al., 2023). In alignment with the literature review undertaken by this thesis, the work presented by Amicosante et al. (2023) also revealed that the focus of studies exploring contact tracing efforts during COVID-19 have primarily focused on proxy data and thus remain limited in scope. However, the authors emphasized the importance of establishing a collectively agreed-upon set of indicators to facilitate comparisons and improvements related to the performance of contact tracing efforts. Finally, Amicosante et al. (2023) also suggested that exploring the development of contact tracing approaches within various contexts is an essential next step for future pandemic planning and contribution to evidence-making within this field.

With the emergence of concerning variants, particularly the Omicron variant, several Canadian public health organizations at various levels – including the local, provincial, territorial, and federal levels – were forced to adapt their approaches to protect populations at

heightened risk (CBC News, 2022). Consequently, several provincial health authorities faced the difficult decision to eliminate broad contact tracing and testing efforts, redirecting the focus toward vaccination, symptom management, and self-isolation when ill (Government of Ontario, 2021).

Although there is a reduced emphasis on contact tracing as a part of the Canadian response to COVID-19, the literature has highlighted the need to investigate how this safety mitigation approach was employed during the pandemic. This would be relevant to informing efforts during future waves of the COVID-19 pandemic or other infectious disease outbreaks. Therefore, this thesis serves a dual purpose. First, by conducting an in-depth exploration of the implementation and use of the DCT approach within a Canadian pediatric specialty care hospital, this research contributes to the existing body of literature on DCT in healthcare organizations. This can provide insights into the implementation and practical use of a DCT approach and may shape management decisions concerning infectious diseases and inform ongoing improvements to DCT approaches. Second, the results of this thesis contribute to the existing research evidence on the implementation and evaluation of DCTs in the hospital context and provide recommendations for future research in this area.

Having established the context of the pandemic and the frequent challenges reported with contact tracing and the current gaps in the literature, I present evidence of how health systems have responded to the pandemic and their use of DCTs to address the challenges faced with traditional contact tracing in the following sections.

Digital Contact Tracing

Existing Use of Digital Contact Tracing

The CDC defines DCTs into three classifications, including case management tools (CMT), medical monitoring tools (MMT) and proximity tracking tools (PTT) (CDC, 2020). Generally, CMTs assist contact tracing by incorporating components of case investigation, contact listing and monitoring, and performance monitoring using automated means. On the other hand, MMTs have been noted to be used as a communication tool between public health departments and necessary contacts during Ebola outbreaks (CDC, 2020). However, MMTs have been primarily used for confirmed and exposed COVID-19 cases to assess the disease severity or the probability of infection with electronic video conferencing. Last, PTTs include various DCT approaches that

utilize smartphone functionality (e.g., Bluetooth and/or Global Positioning Systems) to detect potential infectious disease exposure (CDC, 2020). Often, PTTs are mobile phone applications, wearable technologies, and real-time locating systems (RTLS) (Whitelaw et al., 2020).

However, the notion of using data from smartphones and digital sensors to track and monitor infectious disease dates back to 2010 (Müller & Kretzschmar, 2021), marking its relatively nascent use prior to the COVID-19 pandemic. A systematic review of the use of DCT approaches found four studies describing the use of smartphone applications to support community contact tracing during Ebola outbreaks. After exploring these articles in more detail, an apparent finding was that these applications improved data management, completeness, and access to relevant data for informing decision-making (Danquah et al., 2019; Sacks et al., 2015; Schafer et al., 2016; Tom-Aba et al., 2015).

In the context of the healthcare environment, few reports have demonstrated the uses of DCT approaches prior to the onset of COVID-19 (Hellmich et al., 2017; Oza et al., 2017; Usiak et al., 2015). In an Ebola treatment center, Oza et al. (2017) built and implemented a stand-alone electronic medical record (EMR) system to address the frequent challenges experienced when documenting necessary surveillance information. Similarly, Usiak et al. (2015) utilized EMR to reduce traditional contact tracing efforts during an outbreak of TB within an oncologic unit. Both studies reported that the benefits of leveraging EMRs during contact tracing were the automation of data management, analysis, and reporting. In contrast, Hellmich et al. (2017) reported that the use of RTLS doubled the number of potential pertussis exposures within an emergency department compared to EMR review. Collectively, these articles demonstrate early evidence of the use and adoption of DCT approaches to address the challenges of monitoring and tracing infectious disease outbreaks. Further details on the use of DCTs within the hospital context specific to the COVID-19 pandemic are provided in the following section.

Digital Contact Tracing During COVID-19

Various technologies have been developed and implemented around the globe to mitigate the consequences of the pandemic, reduce the rate of transmission, relieve pressure on health systems, and preserve supplies (Baumgart, 2020; Golinelli et al., 2020). Overall, the intended use of DCTs has been to electronically collect information to reduce disease transmission (Osmanlliu et al., 2021). However, these technologies have also been leveraged to identify and trace those

who are potentially infected, locate close contacts, and enforce health measures (Anglemyer et al., 2020; Mao et al., 2021; Whitelaw et al., 2020). However, other anticipated benefits of DCT have been reported, such as facilitating automatic data entry, real-time information on probable or confirmed COVID-19 cases, and improvements in the accuracy of data and data management (Anglemyer et al., 2020; Katehakis et al., 2020). Finally, DCT has also been noted to inform individuals about what to do after exposure to a positive COVID-19 case, such as self-isolation requirements, testing protocols, and how to monitor symptoms at home (Blasimme et al., 2021). As a variety of contact tracing technologies have been developed and implemented in response to COVID-19 challenges and constraints, the literature has failed to identify a standard for DCT innovations.

Several federal public health agencies around the globe have rapidly developed technologies to alleviate the logistical challenges often encountered in traditional contact tracing (Grekousis & Liu, 2021). In a recent scoping review, 180 different applications and technologies across 90 countries were identified to be implemented within community settings to prevent the spread of COVID-19 (Bardus et al., 2022). Among the countries reported, Bardus et al. (2022) found that the majority of DCT applications were implemented in the United States (20%) and Australia (3.3%), with Germany, Great Britain, India, and the Philippines representing 2.8% of all applications. Notably, Bardus et al. (2022) identified Canada to be in the bottom 1.1% compared to other countries, with only 2 technologies developed to support contact tracing during the pandemic.

In Canada, the two Bluetooth PTTs utilized during COVID-19 were developed by the federal government and the Alberta government. The Government of Canada's 'COVID Alert' application aimed to notify individuals who were in proximity to a self-identified COVID-19 positive case (Gao et al., 2022). As of June 2022, COVID Alert was decommissioned because of the public health situation improving in Canada. It was estimated that only 6.9 million Canadians downloaded the COVID alert, representing 18% of the country's population (CBC, 2022). Similarly, the Alberta Government's 'ABTraceTogether' application was reported to have only a 7% provincial uptake (Gao et al., 2022). Through the cross-sectional study conducted by Gao et al. (2022), the primary reported reasons why Canadians refrained from downloading federal and provincial DCT applications were related to privacy concerns and a lack of perceived benefits.

Privacy concerns and the perceived benefit of DCTs are not limited to the Canadian context. Similar findings related to public attitudes toward, use of, and acceptability of DCTs have been frequently documented in the literature (Anglemyer et al., 2020; Bardus et al., 2022; Juneau et al., 2023). In a scoping review, it was reported that several additional factors influenced the public's acceptance and adoption of DCTs during the COVID-19 pandemic. These determinants were primarily related to trust and political beliefs, a sense of social responsibility to reduce transmission, the perceived threat of COVID-19, an individual's experiences with and access to technology, the functionality of the technology, and the presence of an intention-action gap (e.g., intention to use technology but no action taken to utilize it) (Zetterholm et al., 2021). Moreover, Zetterholm et al. (2021) also pointed out that despite the increase in DCTs implemented during the pandemic, there is a shortage of studies exploring valuable insights into users' perspectives within the unique context. To address this gap and to make further contributions related to the understanding of preventive technologies, Zetterholm et al. (2021) suggest that qualitative studies are warranted.

A major observation of the literature is that there is a predominant focus on the impact and uptake of DCT approaches within the community setting during COVID-19, including observational and modeling studies. However, researchers have also underscored the importance of understanding how healthcare environments have applied technologies to mitigate or solve challenges imposed by the pandemic (Golinelli et al., 2020). In the upcoming section, I explore the literature and provide insights into how various DCTs have been applied in healthcare environments to address ongoing challenges posed by the COVID-19 pandemic.

COVID-19 in Hospitals

Challenges faced during the COVID-19 Pandemic

On a global scale, protecting the health and safety of HCWs has been a persistent challenge during the pandemic (Qi et al., 2020). In Canada, each pandemic wave has confronted health systems with finding a balance between caring for COVID-19 patients and treating non-COVID-19-related health issues (Canadian Medical Association, 2021). Nonetheless, difficulties have been exacerbated by an increasing shortage of HHR (Canadian Medical Association, 2021).

The COVID-19 pandemic has also challenged hospitals to become potential hubs for transmitting the virus. Several challenges exist in diagnosing, quarantining and treating

suspected or confirmed COVID-19 cases in this setting (Haleem et al., 2020). This has been suggested to be a result of the increase in COVID-19 patients combined with the interconnected interactions and collaborative nature of the healthcare environment (Emecen & Keskin et al., 2021). To prevent nosocomial COVID-19 transmission, most hospitals have implemented and continued pandemic responses, plans, and strategies. At large, these have focused on internal infection control policies and protocols, such as routine personal protective equipment (PPE) use, environmental controls and distancing restrictions, self- or work-isolation measures, and vaccination policies (PHO, 2022b).

The healthcare workforce was demonstrated to be an extremely valuable yet scarce resource throughout the COVID-19 pandemic. All Canadian healthcare systems have been challenged by the demands for extra capacity, coupled with a workforce experiencing additional pressures and extreme burnout (CIHI, 2022). Despite HCWs working an average of eight overtime hours per week in 2021 (CIHI, 2022), Canadian health systems have experienced an increase in staff shortages. By February 2022, the number of infections among Ontario HCWs had surpassed 30,000 (PHO, 2022a). Consequently, inadequate staffing infrastructures forced hospitals to adjust their services, impacting the delivery of care in Canada. For example, a few rural Ontario hospitals were faced with the difficult decision to halt emergency services during the Omicron variant as a result of nursing and physician shortages (Sandstrom et al., 2022). Although circumstantial policies allowed many positive HCWs to return to work under additional precautions, the increase in nosocomial infections as a result of the Omicron variant raised concerns over what more can be done to protect patients and HCWs (Klompas & Karan, 2022). As a result, monitoring the healthcare workforce and the capacity of Canadian healthcare systems has been identified as an ongoing priority throughout the COVID-19 pandemic (CIHI, 2022).

Although the factors imposed on Canadian health systems by the pandemic are multifaceted and go beyond the scope of this thesis, this section has provided an overview of prominent impacts and challenges faced because of the increased number of HCW infections. Collectively, these factors underscore the importance of hospitals maintaining accurate and effective surveillance programs to protect the health and safety of their workers and patients. Moreover, such programs and policies are essential for addressing system capacity challenges, whether they are linked to the COVID-19 pandemic or other infectious disease threats. In the following

paragraphs, I present an overview of the role of contact tracing within hospitals. Additionally, I explore how electronic surveillance systems, such as DCT, have been deployed during the pandemic in hospitals. Finally, I describe the challenges presented among various types of DCT approaches employed within this context.

Contact Tracing Overview

Under the *Health Protection and Promotion Act*, hospitals in Ontario have obligations to report probable or confirmed hospital-acquired infections of significant public health concern to their respective public health officials (Health Protection and Promotion Act, 1990). Additionally, the Ontario Public Hospitals Act mandates that each hospital establish and provide communicable disease surveillance programs (Public Hospitals Act, 1990). By reporting outbreaks in hospitals, the epidemiology of various viruses can be assessed and thus is essential for informing timely control measures (PHO, 2020). In addition to the aforementioned Acts, PHO has stated various requirements for healthcare facilities to have surveillance programs to detect and track patient and staff cases of COVID-19 (PHO, 2021a).

In parallel with the community, healthcare environments have swiftly implemented internal strategies to maintain their workforce during the COVID-19 pandemic (Stuart et al., 2020). To contain the transmission of COVID-19, many studies have highlighted the importance of early recognition of index cases and prompt isolation to reduce hospital transmission rates. However, the occupational complexities existing in hospitals have created challenges for efficiently exercising contact tracing (Breeher et al., 2020). Throughout the pandemic, hospitals have continued to be confronted with the need to balance infection control and HCW shortages (Sahoo et al., 2021). As the previous paragraphs indicated, several HCWs infected with COVID-19 are not only problematic for health and safety but also pose detrimental effects on the capacity of health systems (Tang et al., 2021; Vargese et al., 2021).

Throughout the pandemic, various evidence-based guidelines and advice have emerged from governing bodies in Ontario for the prevention and control of healthcare-acquired infections. During the time of writing this thesis report, the most recently updated case and contact management guidelines from the Ministry of Health and Long-Term Care (MOHLTC) were released on March 23, 2023. Within this guidance, public health units are no longer expected or required to conduct individual-level contact tracing. Similarly, identifying and notifying close

contacts of COVID-19 in acute care settings (e.g., hospitals) remains the responsibility of the institution. Although HCWs have been recommended to communicate with their employer upon testing or being symptomatic for COVID-19, there is no provincial mandate to employ contact tracing.

This section has demonstrated challenges in employing effective contact tracing in the hospital setting. Of most implication, the time requirements and HHR constraints with traditional approaches for contact tracing pose a significant risk of delays in identifying and isolating COVID-19 exposures. Considering the implications posed on health systems throughout the pandemic, effective contact tracing is crucial for protecting the safety of HCWs.

Overview of Digital Contact Tracing

Throughout the pandemic, there has been a gradual increase in the number of publications concerning the use of DCT approaches within hospitals, particularly between 2021 and 2022. Many of these publications have used observational, cross-sectional, or mathematical modeling research designs. Furthermore, many of these studies' primary aims are to evaluate the risk of COVID-19 spread or describe the characteristics of transmission. Studies providing detail on the components or the development of DCT approaches have been less frequently reported in the literature, although some do exist (Breeher et al., 2020; Llupià et al., 2022; Mak et al., 2021; Zirbes et al., 2021). The origin of these publications has widely varied, including Europe (Germany, Spain), Australia, Asia (Hong Kong, Singapore, South Korea, Malaysia, Saudi Arabia), and the United States.

The software and technologies used for hospital-based DCTs have also differed considerably. Reports have highlighted the application of different digital tracking and monitoring technologies, such as EMRs, closed-circuit television (CCTV), RTLS, radio-frequency identification (RFID) systems, Wi-Fi access point logs, and Bluetooth data-based systems (M. N. Aung et al., 2021; Chambers & Anglemyer, 2022; Curtis et al., 2021; Ho et al., 2020; Hong et al., 2021; Jung et al., 2022; Mak et al., 2021).

Several studies have also detailed the use of web-based and integrated online DCT applications to augment hospital-based contact tracing (Abdul Muthalib et al., 2023; Bechmann & Geginat, 2022; Breeher et al., 2020; Llupià et al., 2022; Vargese et al., 2021; Wan et al., 2021; Zirbes et al., 2021). For example, Zirbes et al. (2021) describe the development of a web-based

contact tracing and point-of-care-testing workflow. Similarly, Breeher et al. (2020), Wan et al. (2021), and Vargese et al. (2022) describe different types of integrated online portals that allow staff to submit electronic forms related to COVID-19 case investigations. Comparably, Llupià et al. (2022) describe the utilization of two software programs, including REDCap and the WHO-developed software 'Go.Data'. To reduce multiple manual steps and to facilitate automated follow-up, Llupià et al. (2022) also describe how these technologies were expanded to develop an in-house solution. Bailie et al. (2021) also reported utilizing REDCap as a data management tool among contact tracers. Bechmann & Geginat (2022) and Abdul Muthalib et al. (2023) describe the use of a spreadsheet tool and risk categorization tool designed to aid in various contact tracing processes, respectively.

It is important to highlight that most studies did not identify relying on a single contact tracing strategy exclusively. Rather, DCT approaches were frequently leveraged alongside traditional contact tracing methods (when applicable) or in conjunction with other technologies. This further highlights the lack of a universally adopted DCT or a "one size fits all' approach" (Aung et al. 2023, p. 17).

Additional details on the reported advantages and disadvantages of these DCT approaches are provided in the subsequent paragraphs.

Evidence of Digital Contact Tracing

A common theme noted across studies employing tracking and monitoring technologies, such as PTTs, is the ability to have greater accuracy in determining the movements of HCWs and timely identification of close contacts (M. N. Aung et al., 2021; Chambers & Anglemyer, 2022; Curtis et al., 2021; Jung et al., 2022; Mak et al., 2021). Similarly, Ho et al. (2021) and Aung et al. (2023) concluded that utilizing RTLS and EMR data for hospital-based contact tracing exhibited greater accuracy in both sensitivity and specificity when compared to traditional approaches. However, limitations pertaining to PTTs have also been documented. Challenges often stem from the significant costs associated with this technology use and maintenance, the lack of adequate information on the interactions, issues with compliance, and privacy concerns (M. N. Aung et al., 2021; Jung et al., 2022; Ostovari et al., 2020).

The primary advantage reported when augmenting contact tracing through the review of EMR data was the capacity to query different types of clinical events that may have occurred

during HCW and patient encounters (M. N. Aung et al., 2021; Hong et al., 2021). Nevertheless, the review of EMR data is also reported to have limitations as a result of its time-consuming nature, combined with the challenges of accurately recording interactions (M. N. Aung et al., 2021; Ho et al., 2020; Hung et al., 2020). For example, Hong et al. (2021) reported that EMR reports were not sufficient for identifying interactions between patients and hospital support staff, including those whose responsibilities did not necessitate EMR access or those with limited access to patient records.

Studies utilizing web-based and integrated online applications for DCT found that these technologies standardize processes, increase the speed of containing COVID-19, and improve the overall efficiency of contact tracing efforts (Bechmann & Geginat, 2022; Breeher et al., 2020; Wan et al., 2021; Zirbes et al., 2021). Specifically, the outcomes of downstream contact tracing activities have been related to manpower utilization, early detection and risk categorization among HCWs, and the implementation of safety protocols to reduce transmission (Abdul Muthalib et al., 2023; Bechmann & Geginat, 2022; Breeher et al., 2020; Zirbes et al., 2021). Finally, an additional key positive outcome reported from utilizing DCTs is the ability to automate instructions to staff regarding the necessary contact precautions according to their risk exposure, as well as the auto generation of surveillance reports (Bechmann & Geginat, 2022; Wan et al., 2021). However, the use of web-based DCT approaches also has limitations. For instance, Zirbes et al. (2021) stated that the success of this approach for contact tracing hinges on the accuracy and reliability of the data input into these technologies. Another limitation noted by Wan et al. (2021) is that staff can be reluctant to use technology-based contact tracing applications.

To the best of my knowledge, two existing studies have reported utilizing REDCap as a hospital-based DCT. First, Bailie et al. (2021) enhanced data management for contact tracing teams in a large health system by employing REDCap. Since REDCap was utilized as a supplementary tool following the completion of traditional contact tracing (e.g., interviews), Bailie et al. (2021) reported that this DCT approach still necessitated a substantial workload. Llupià et al. (2022) identified that REDCap was utilized among multiple other information systems, such as the WHO's developed 'Go. Data' software for hospital surveillance and control among patients and HCWs during the pandemic. Collectively, Llupià et al. (2022) indicated that these technologies reduced COVID-19 infection among patients and HCWs, facilitated the

management of surveillance information, and allowed interventions to be focused on COVID-19 transmission. In addition to this DCT approach involving nearly 200 individuals for its operations, Llupià et al. (2022) also listed that the cross-functional collaboration of these technologies necessitated the involvement of various departments within the hospital.

In light of the evolving pandemic scenario, researchers have reported a stronger case for DCT in high-risk settings such as healthcare environments (Chambers & Anglemyer, 2022). However, apart from simply acknowledging the use of a DCT approach, some current studies have reported low-quality evidence pertaining to how these technologies were employed for contact tracing (Bailie et al., 2021; Curtis et al., 2021; Mak et al., 2021; Vargese et al., 2021). This was particularly evident in studies that aimed to quantify the risk of COVID-19 exposure among HCWs or retrospectively describe activities related to case investigations.

While the literature provides valuable insights from a hospital and policymaker perspective on the use of DCTs, current studies have lacked the ability to offer comprehensive insight into the perspectives of adopters regarding the benefits and challenges they have encountered. In this regard, research has emphasized the importance of assessing the performance of DCT approaches in real-world settings and assessing the acceptability within these contexts (Chambers & Anglemyer, 2022). Additionally, as previously noted, the utilization of DCT approaches in Canadian health systems remains a largely underexplored area. Therefore, this thesis aimed to conduct an in-depth exploration of stakeholders' perspectives on the implementation, utilization, and impacts of the DCT approach that was extensively employed at a specialized pediatric hospital during the COVID-19 pandemic. The following sections describe the conceptual framework guiding this study, followed by a description of the methodology used.

Conceptual Framework

RE-AIM Framework

The Reach, Effectiveness, Adoption, Implementation and Maintenance (RE-AIM) framework (Glasgow et al., 1999) was used as a guiding framework for this research. The RE-AIM framework was first published by Glasgow et al. (1999) to address delays in research translation into healthcare practice and policies. Glasgow et al. (1999) emphasize that the RE-AIM framework focuses not only on evaluating the effectiveness of an implementation but also on assessing its reach and representation across participants and settings. More recent applications of RE-AIM have demonstrated how this framework can be used to address

pragmatic questions concerning the effectiveness of implementations. As demonstrated by Holtrop et al. (2018), this encompasses identifying what works, understanding the settings in which interventions yield results, and recognizing the negative aspects.

While the RE-AIM is often presented quantitatively, there has been a recent focus on qualitative methods uses of this framework (Gaglio et al., 2013; Glasgow et al., 2019; Holtrop et al., 2018). When used for qualitative research, the RE-AIM framework provides in-depth insights into the outcomes of interventions, such as how adaptations were made to interventions, who was involved in the change, and why changes were made (Holtrop et al., 2018). As qualitative methods emphasize the context and settings in which the interventions are implemented, this can be especially beneficial for gaining practical implications of interventions (Holtrop et al., 2018). Qualitative uses of RE-AIM have also been reported to help "understand who is or isn't adopting or delivering the program well, what's required for sustainability, and making refinements to the program over time to ensure overall quality" (Kwan et al., 2019, p.6).

Although the RE-AIM was initially intended to facilitate evaluation efforts, Gaglio et al. (2013) identified that this framework can be utilized at all stages of research, including planning, evaluation, and reporting. Therefore, I assert that the RE-AIM model is well suited to evaluate the use of DCTs during COVID-19 in the hospital context for multiple reasons. First, RE-AIM is considered an appropriate framework for exploring interventions at both the individual level and the organizational level (Gaglio et al., 2013; Glasgow et al., 2019; Holtrop et al., 2018). This is relevant in the context of the present study, as I aimed to gain perspectives from multiple stakeholders regarding the outcomes of DCT and its impacts on hospital processes and HCWs. Second, qualitative exploration of the dimensions of the RE-AIM framework can provide practical guidance for improving interventions and facilitating knowledge translation (Holtrop et al., 2018). Therefore, the findings presented in this thesis are relevant to key stakeholders who wish to inform scale-up initiatives related to DCTs in the hospital context. This may include a range of individuals, such as healthcare administrators and leaders, policymakers, researchers, and technology developers. Table 1 presents a summary of the original definitions of RE-AIM, along with how they have been adapted to fit the context of the present study.

Table 1. RE-AIM Framework Dimensions. Adapted from (Glasgow et al., 1999)

Dimensions	Original Definition (Glasgow et al., 1999)	Study Description

Reach	The absolute number, proportion, and representativeness of individuals who are willing to participate in each intervention or program.	The individuals who intended to be reached by the DCT tool. The individual-level facilitators/barriers to engagement and non-participation with the DCT tool.
Effectiveness	The impact of an intervention on important outcomes, including potential negative effects.	The impact of the DCT tool based on its perceived outcomes (intended and unintended). Includes stakeholders perceived measures of DCT effectiveness.
Adoption	The absolute number, proportion, and representativeness of settings and the individuals within those settings who are willing to initiate an intervention.	The factors influencing DCT adoption at the setting-level. Namely, facilitators and barriers.
Implementation	The fidelity of the intervention. Includes how well an intervention was been delivered, costs of interventions, and the consistency across time with which an intervention was delivered.	The process of implementation and challenges experienced during implementation. Investigates how closely DCT was delivered as intended.
Maintenance	The extent to which an intervention becomes institutionalized or part of routine practices. Includes how interventions have been adapted long term.	How DCT became institutionalized, including the modifications and sustainability.

The RE-AIM framework has demonstrated utility in evaluating interventions and implementations across numerous bodies of literature, including public health and healthcare contexts. However, this framework has also helped assess technology-based interventions in healthcare, such as virtual emergency medicine curricula, computer-based HIV prevention, technologies for improved diabetes management, and telerehabilitation (Hale-Gallardo et al., 2020; Miller et al., 2020; Nagji et al., 2020; Noar, 2011; Steinman et al., 2020).

Few studies exploring contact tracing in the community setting have utilized the RE-AIM framework. However, these studies have focused on traditional approaches to contact tracing and exploring the perspectives of case investigators (Shelby & Hennein et al., 2021; Shelby & Schenck et al., 2021). Overall, the authors of these studies concluded that utilizing the RE-AIM framework added strength and clarity to their findings while also proposing solutions to enhance contact tracing practices for current and future pandemics.

Methods

Setting

This project was conducted in the context of a pediatric specialized acute-care hospital in the province of Ontario. It is located in Ottawa and serves a catchment of over 500,000 children and youth per year, aged 0-17 years, from the Champlain region, Western Quebec, regions of Nunavut, and Northern Ontario (CHEO, 2021a). Employing over 3000 staff and healthcare professionals, CHEO provides a broad range of pediatric inpatient and outpatient specialist services across eight departments and 38 subspecialties (CHEO, 2021a).

CHEO has implemented several infectious disease protocols to limit the spread of transmission. For the majority of the pandemic, all persons entering the CHEO (e.g., patients, caregivers, staff, volunteers, students, and contractors) had to undergo rigorous entrance screening that assessed symptoms and possible COVID-19 exposure (CHEO, 2021b). Additionally, CHEO also followed provincial infection prevention and control guidelines upon outbreaks being declared within the hospital and on the units. Throughout the stages of the COVID-19 pandemic, additional safety precautions were also taken, such as minimizing crowding by assigning designed entrances, ensuring adequate physical distancing in all public and private areas, temperature screening, and requiring the use of face masks for employees and caregivers (CHEO, 2021b). At this stage of the COVID-19 pandemic, various changes to infection protocols have been made. For instance, on March 8^{th,} 2023, CHEO moved to passive screening (e.g., using signage upon entry) for patients and families.

Digital Contact Tracing at CHEO

Overview

In addition to the above protocols, CHEO has also implemented rigorous contact tracing for COVID-19. During the onset of the pandemic, CHEO created a COVID-19 Safety Team (CST) to facilitate case and contact management among staff. This team consisted of registered nurses, nurse practitioners, and licensed practical nurses who worked under the Occupational Health and Safety Department. The CST played a pivotal role in COVID-19 contact tracing by extracting information from hospital records, including sign-in sheets, assignment documents, and searching within the EMR (Epic System). This information was then used to identify either patients or staff who may have had possible contact with positive cases during the period of communicability. However, it is important to note that distinctive processes existed for contact

tracing among COVID-19-positive staff and patients. While the CST's efforts were focused on COVID-19 exposure among staff members, the Infection Protection and Control (IPAC) team focused on patients.

The COVID-19 contact tracing process was initiated with the IPAC team or the CST being notified of a positive COVID-19 case among patients or staff. In cases involving positive staff members, the CST then distributed the REDCap survey (hereinafter referred to as the "DCT tool") to potentially exposed staff members to assess the level of COVID-19 exposure (Appendix A). The DCT tool consisted of validated measures primarily related to the staff's (1) demographic and institutional details (e.g., role within the hospital, department, email for follow-up), (2) details on case contact, (3) proximity of the COVID-19 case, (4) aerosol medical procedures with potential contact, (5) personal protective equipment (PPE) usage, (6) symptoms, and (7) COVID-19 testing/testing outcomes. It is important to note that the CST distributed the DCT tool exclusively to staff members. As IPAC had distinct contact tracing processes in place for patients and caregivers, they did not receive the DCT tool.

Using the information obtained from the staff, the embedded algorithm within the DCT tool determined the level of exposure, categorizing staff as high- or low-risk. Once staff completed the DCT tool, they received automated guidance via email, outlining protocols (e.g., isolation, testing, return-to-work procedures) based on their submitted information. In the event of a staff member testing positive for COVID-19, the CST distributed another REDCap survey to gather further details on transmission and document nosocomial exposure. Although various REDCap surveys were used at CHEO in response to COVID-19, this study specifically investigates the tool employed for contact tracing among staff.

Since the implementation of the DCT tool (June 10th, 2020), approximately 11,604 risk-assessments have been completed (CHEO OHS-COVID, personal communication, September 14, 2023). Among these, staff completed the DCT tool as a result of probable contact with positive patients in 75% (n=8726) of completed assessments (CHEO OHS-COVID, personal communication, September 14, 2023). While possible contact with positive staff accounted for 21% (n=2425), less than 4% (n=453) of the completed assessments were a result of possible positive caregiver contact (CHEO OHS-COVID, personal communication, September 14, 2023). Furthermore, the DCT tool has been distributed to various units and departments across the hospital. However, it was suggested that staff working within the inpatient medicine unit, the

emergency department, the hematology department, and the screening team tended to have higher rates of completed entries (CHEO OHS-COVID, personal communication, September 14, 2023).

Current State

As of May 4th, 2023, CHEO moved to "symptom-based" management for COVID-19. Subsequently, this approach discontinued testing and contact tracing for COVID-19 among all staff (CHEO OHS-COVID, personal communication, July 13, 2023). Rather, staff reporting one or more COVID-19 symptoms are asked to work-self isolate for up to 10 days (CHEO OHS-COVID, personal communication, July 13, 2023). Nonetheless, staff have been directed to self-monitor for symptoms of COVID-19 and utilize the REDCap screening tool when requiring guidance on protocols that must be followed. Staff with any COVID-19-related symptoms are no longer expected to self-isolate for 24 hours upon having symptoms (48 hours for gastrointestinal symptoms) or are required to stay at home until their symptoms have improved (CHEO OHS-COVID, personal communication, July 13, 2023). Given that this study commenced before the transition of case-by-case and "symptom-based" management, its focus is on the DCT approach employed throughout the majority of the pandemic (as described above). The contact tracing process at CHEO is depicted in Fig 1.

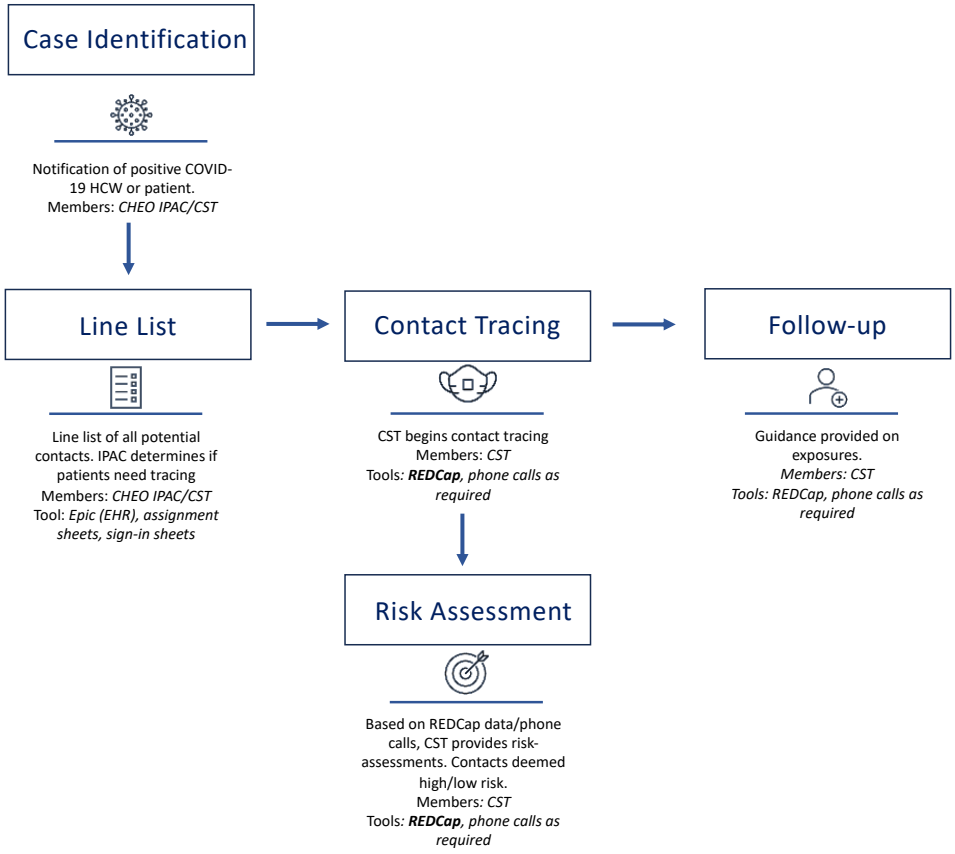

Figure 1. COVID-19 Contact Tracing Process at *CHEO* (CHEO, personal communication, November 24, 2021).

Data Collection

Research Design

This study followed an exploratory qualitative design based on semi-structured interviews. Qualitative approaches have also demonstrated the ability to inform evidence-based decision-making on emerging issues and situations within health services research, practice, and policy (Bourgeault et al., 2010). As qualitative research seeks to uncover the experiences and beliefs of a phenomenon of interest (Hennink et al., 2020), it is an appropriate methodology to explore the research question posed in this study.

As previously mentioned, research on DCT within the healthcare context has predominantly focused on quantitative outcomes regarding outbreaks and transmission events among HCWs and patients. Therefore, this study aims to complement the literature by generating

an in-depth understanding of the implementation, utilization, and acceptance of the DCT approach within the healthcare environment that cannot be captured through quantitative data alone. Last, there has also been a recent push for more practical uses of the RE-AIM framework. Glasgow et al. (2019) describe that pragmatic use of the framework should focus on the dimensions of most value to the particular question being asked, the setting, stakeholders, and the research stage. Moreover, in qualitative inquiry, pragmatism can "seek practical and useful answers that can solve, or at least provide direction in addressing concrete problems" (Patton, 2015, p.152). Given the need to explore DCT from a practical standpoint, I adopted pragmatism as a research paradigm for this thesis research.

Recruitment

Public hospitals are required to consider the interests of multiple stakeholders within their health system (Ontario Hospital Association, 2015). Due to their unique experiences, stakeholder groups within this complex and diverse setting offer diverse perspectives on issues in healthcare (Rycroft-Malone et al., 2016). Furthermore, in recent publications, there has been an emphasis on the scarcity of literature exploring users' perspectives on the use of DCTs during the COVID-19 pandemic (Osmanlliu et al., 2021; Zetterholm et al., 2021). Since similarities exist in the principles of contact tracing between the community setting and a hospital context, this thesis adopted the recommendations provided in the literature by soliciting the participation of stakeholders who experienced implementing DCTs and those who have utilized them in various ways. Specifically, participants were recruited for this study based on their involvement in the following three groups:

1. *Healthcare administrators/managers* involved in conceptualizing and implementing the DCT tool. These participants are referred to as "Implementors" throughout the study.
2. *Occupational specialists* who make decisions based on the data obtained from the DCT tool (e.g., past or present members of the CST). These participants are referred to as "Occupational Specialists" throughout the study.
3. *HCWs acting as end-users* of the DCT tool. These participants are referred to as "End-users" throughout the study. For this study, end-users were defined as healthcare personnel who may have been exposed to COVID-19 at CHEO and had utilized the

DCT tool. All healthcare personnel were eligible for this study, including regulated healthcare professionals and hospital support staff.

Purposeful sampling permits the selection of information-rich participants to best inform the understanding of the phenomenon of interest (Patton, 2015). This research used a purposeful and snowball sampling approach to solicit the participation of various stakeholders. Primarily, the thesis committee members facilitated contact with potential participants. Snowball sampling was also employed, in which study participants were asked to recommend other individuals whom they believed would be suitable for participation in the study.

Recruitment of participants was not without challenges for this thesis. First, recruiting individuals who met the implementor and occupational specialist criteria was challenging due to the small pool of individuals who appropriately fit the recruitment criteria. Second, the demanding responsibilities placed on HCWs coupled with the prevalent issue of burnout faced throughout the COVID-19 pandemic posed significant challenges in the recruitment process. To facilitate recruitment and as a token of appreciation for participating in the interview, end-users received a $20 honorarium in the form of CHEO gift cards.

Data Sources

In this study, the primary data source was transcripts from semi-structured interviews. All interviews were guided by the RE-AIM framework (Appendix B). The interviews aimed to explore participants' perspectives on the implementation and impacts of the DCT tool. All participants were asked to provide their perspectives on the DCT tool's generated benefits, challenges, and perceived effectiveness during the COVID-19 pandemic.

The interviews were conducted over a 4-month period, starting in December 2022 and ending in April 2023. Interview guides were tailored to match the role of each stakeholder group. However, similarities existed across the three guides to enable cross-comparisons between stakeholder groups, such as the participants perceived benefits, challenges, and effectiveness of using the DCT tool during the COVID-19 pandemic. Pertaining to differences, implementors were asked to describe the implementation process, while occupational specialists were probed on the specific aspects of conducting case investigations through a DCT tool. Conversely, end-users requested to provide insights into their experiences using the DCT tool compared to the traditional approach taken by Ottawa Public Health (when applicable). Due to the ongoing

challenges of the COVID-19 pandemic and hospital capacity concerns, all interviews were conducted using either a virtual platform (Microsoft Teams) or a telephone call. The interviews lasted on average 33.6 minutes, ranging from 13 to 49 minutes, depending on the participants' time and experience with the DCT tool.

Data Management

To facilitate the analysis, all interviews were digitally audio-recorded and transcribed verbatim using Otter.ai. Once transcripts were carefully read and edited, they were entered into NVivo (QSR International, Melbourne, Australia), which is a computer-assisted qualitative data analysis software. All study data were pseudonymized to ensure anonymity and stored in a secure, password-protected computer. Ethics approval was obtained from the Children's Hospital of Eastern Ontario Research Ethics Board and the University of Ottawa Research Ethics Board before commencing the research. Further detailed information on the ethical considerations is presented in the following section (Ethical Review and Considerations) and information on the ethical forms utilized throughout the study (e.g., cover letter, consent form, ethics amendments) can be found in Appendix C.

Data Analysis

Data analysis was conducted using Braun & Clarke's (2006) approach to thematic analysis for analyzing, identifying, and conveying patterns found within the qualitative. As outlined by Braun & Clarke (2006), thematic analysis employs a systematic yet flexible approach to exploratory research. This analytical approach enabled me to explore the nuanced perspectives of the DCT tool impacts while also understanding the complex factors and challenges related to its implementation and utilization in the hospital context. My analysis followed the six stages outlined by Braun & Clarke (2006), including (1) data familiarization, (2) systematic coding, (3) generating initial themes, (4) developing and reviewing themes, (5) refining, defining, and naming themes, and (6) write-up. Additionally, following the approach described by Miles et al. (2020), I also summarized the information gained from each interview utilizing a Contact Summary Form (Miles et al., 2020). This served as a tool for documenting the main issues and concepts discussed during the interview, as well as identifying any new (or remaining) questions that should be explored in future interviews.

Data Familiarization. The first step involved familiarization with the data by thoroughly reading the transcripts and memos I wrote during the interview. A subset of transcripts was randomly selected and independently double-coded by myself and a colleague who has received training in qualitative analysis. Following Miles et al.'s (2020) approach to coding, we used descriptive codes to condense data passages in words or short phrases and In Vivo codes to denote data passages in the participant's words.

Generating Initial Codes. After conducting line-by-line coding on the six transcripts, my colleague and I met to discuss our findings and resolved any inconsistencies through discussion. Following Miles et al.'s (2020) agreement (e.g., the number of aligned codes/the total number of codes per study), the coder agreement was calculated to be 83.5% (range: 76.8-89.6%). After the six transcripts had been independently coded and reviewed, the percent agreement was determined by comparing the codes assigned by myself and my colleague and then averaging the agreement percentages. Code disagreements were recorded when (1) coders did not identify a code in the transcript and (2) coders had different interpretations of the transcript. See below for an example. As this research was largely inductive, we used line-by-line coding to generate preliminary ideas on the initial six transcripts. This helped to organize the emergent codes into categories and resulted in the development of the initial codebook.

> *Example of disagreement:* In the excerpt from P14 (End-user), *"I didn't have any errors in terms of the form and that."* One coder perceived this as "errors of the tool" while the other coder perceived this to be "ease of use." After meeting to discuss our codes, we determined that this participant quote was better represented by "ease of use" as they stated that they encountered no errors while completing the DCT tool.

As this process continued, codes that emerged from the data that were reflective of important concepts became the initial codebook. Subsequently, a codebook was developed and validated by myself and my colleague. Next, I utilized this codebook to independently recode previous and remaining transcripts in NVivo. At this stage, I took a focused coding approach which involved segmenting data from the transcripts at a higher level. This approach was subsequently applied to the entirety of the data set. The codebook was continuously revised and adapted to fit emerging codes throughout the analytical process. The final codebook included all codes used in the study, a description of the code criteria, and when to apply the code to the data (Hennink et al., 2020).

Searching for Themes. After coding all the transcripts, codes were then organized into broad categories. During this process, I examined the generated codes in each transcript to pinpoint underlying concepts and how different codes were related or linked. To facilitate this process, codes were consistently documented, and notes were made to distinguish relationships between recurrent and similar codes. By reflecting on the emerging data, adding nuances, and probing further into the meaning within the categories, initial themes started to develop.

Refining Themes. Once initial themes were generated, I reviewed the codes and emergent themes to compare and ensure that themes continued to accurately reflect the data set. This also included examining the coded data to ensure coherence and consistency. I reviewed the data from the participants and other study materials (e.g., transcripts, memos, and interview notes) to ensure that the initial themes accurately represented the participants' perspectives. During this step, I conducted repeated cross-case comparisons to refine the themes and identify core concepts that accounted for different perspectives among the stakeholders. Table 2 highlights a few excerpts of my memos during this stage of the analysis.

Table 2. Analytical Memos

Memos
There appears to be some aspect of personal attitude/perceived value towards the electronic nature of the DCT. Some attitude towards implementation/perceived value of its use. It is important to contrast this with the shift in perspective throughout the course of the pandemic.
Efficient data governance is emerging as a main concept about the benefits of DCT. This concept may align with "informed decision-making." However, participants have perceived distinct aspects of the two concepts. Participants have described data governance as the ability to have a reproducible, reliable, and secure response to identify and contain COVID-19. Whereas informed decision-making describes the actionable impacts of the DCT from an organizational and individual level.
In the early stages, COVID-19 was constantly changing. There was constantly new information, data, and policies regularly emerging. It has been a highly unpredictable disease with multifactorial uncertainties, such as sudden surges in cases and changes in transmission patterns (which have been amplified in the healthcare setting). This shifting nature of the disease highlights the need for measures and responses to be flexible and adaptable. As well as the need for ongoing monitoring to maintain control and prevent outbreaks. Participants have perceived that the DCT has been able to address and support this evolving situation.

Defining and Naming Themes. During the fifth step, I mapped the emergent themes according to the RE-AIM framework. Additionally, I iteratively reviewed and assigned clear

definitions to the emergent themes and subthemes. Following the approach outlined by Gioia et al. (2012), I created a data structure to facilitate this process and demonstrate how codes became themes. The data structure consisted of three levels: first-order concepts (codes), second-order themes (categories), and aggregate dimensions (themes) (Appendix D). During the sixth and final stage, I documented my findings in a comprehensive write-up, guided by the RE-AIM framework as presented in this thesis.

Writing the Report. After coding all the data, the RE-AIM framework was then applied to provide a structured approach to organizing the data and presenting the results. An overview of the analytical procedures is depicted in Fig. 2. Additional details on the write-up can be found in the Results section.

Inductive and Deductive Approach

I used both inductive and deductive approaches in my analysis. The inductive approach involved assigning labels to codes emerging from the data that represented important concepts. This helps the research to remain open and exploratory, rather than forcing the data to fit predetermined categories (Miles et al., 2020). By employing an inductive approach initially, I aimed to capture a wide range of concepts and start identifying emerging conceptual linkages both within and across transcripts. However, my prior knowledge regarding the use of DCT from the literature influenced aspects of the inductive coding process. For instance, this knowledge prompted the formation of preliminary codes of scalability within the transcripts. However, this also influenced me to engage in a more focused exploration related to the aspect of scalability and what this concept meant from the perspectives of participants within this study. This resulted in three distinct concepts emerging from the concept of scalability including, the DCT tool providing an agile response to COVID-19, its timeliness and broad reach, and its impact in making informed decision making. Additional details on these themes are provided in the Results section.

Deductive approaches were also used to identify and characterize instances of themes in the later stages of the analysis. After the initial inductive phase, I adopted a deductive approach by utilizing the RE-AIM framework to organize and categorize the emergent themes. To ensure consistency in my coding approach across transcripts, I integrated the RE-AIM dimensions

within the codebook. Sub-themes were then further explained and contextualized while also relating to the specific dimensions of the RE-AIM framework.

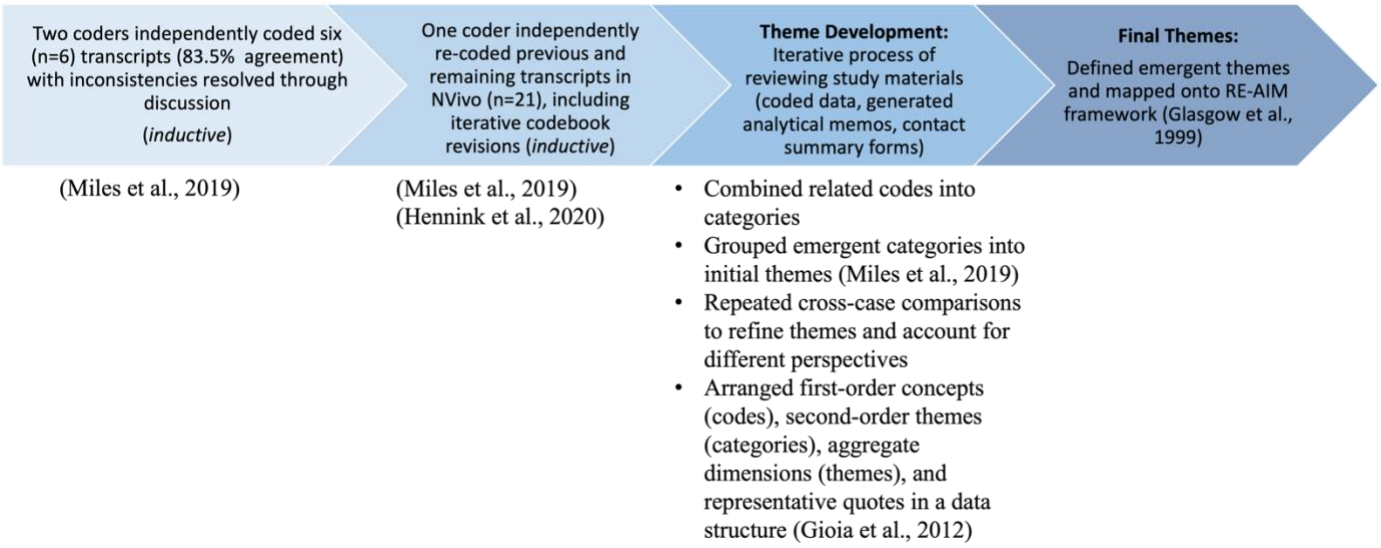

Figure 2. Summary of Analytical Procedures

Ethical Review and Considerations

I distributed the study cover letter and an electronic version of the consent form to potential participants via email. This outlined important information about the study, including its purpose, the steps taken to ensure confidentiality and anonymity, the use of audio recording, and the voluntary nature of their participation in this study. For example, anonymity and confidentiality were ensured by removing direct identifiers from the study data, using pseudonyms, and presenting aggregate data.

Two ethics amendments occurred in this study. As previously mentioned, the recruitment of end-users was facilitated by a CST member rather than committee members. Specific to the recruitment of end-users, the recruitment plan was modified from the onset of the study. Instead of end-users receiving an invitation from the thesis committee members, we engaged a CST member to facilitate identifying and inviting HCWs who met the study criteria. This was chosen because they had access to the database of completed case investigations and the staff who had used the DCT tool. Potential participants were able to contact the research team directly if they were interested in participating. However, potential participants were also able to provide their email addresses to the CST members for the research team to contact them. When this option

was chosen, I contacted the potential participants via email directly. It is important to note that no members from the CST had access to details about participants' study progress or their decisions to participate or decline. Rather, their role was to identify potential participants with information about the study and direct them to the research team. As mentioned, end-users received an honorarium in the form of CHEO gift cards to facilitate recruitment and thank them for their participation.

Potential participants had the opportunity to discuss the study and ask any questions before deciding if they wanted to participate. For those who agreed to participate in the study, I obtained an attestation of consent in the form of an electronic signature on the consent form. Copies of the signed consent forms were saved and stored on a CHEO server for the duration of the study and retention period. To ensure identification authenticity, participants were asked to confirm their name and email address and affirm that they signed the consent form before I started the interview.

Establishing Quality and Trustworthiness

I assessed the trustworthiness of the findings using approaches described by Miles et al. (2020). This consisted of several techniques to ensure this study's confirmability, dependability, creditability, transferability, and application.

To ensure *confirmability*, I took steps to ensure that the methods and procedures of this thesis were well-detailed and explicitly described (Miles et al., 2020). This includes details on how the data were collected, processed, analyzed, and displayed. Moreover, reflexivity is essential in all qualitative research, as it concerns reflecting on the research process and one's role as a researcher (Braun & Clarke, 2006). Braun & Clarke (2006) encourage researchers to practice reflexivity using a research journal. Following this recommendation, I documented any ideas and reflections, decisions made, and interpretations/implicit biases throughout the research process in a journal. I start this early in the research process (e.g., data collection) and continue to document my reflexivity throughout the analysis procedures. For example, I kept detailed notes on the development of themes and subthemes to help establish the confirmability of my findings. I also described my reflexivity as a researcher and its potential impact (see below).

To ensure *dependability*, I actively took steps to ensure the quality and integrity of this thesis by having a well-defined research question, research paradigm, and study design (Miles et al., 2020). Throughout the data analysis process, I obtained assistance from an external colleague

who supported me in reviewing data (e.g., transcripts), the data interpretation process (e.g., coding), and process materials (e.g., memos and initial codebook).

To demonstrate *credibility*, the findings of the study have been clearly communicated while also providing appropriate depth into the context of this study (Miles et al., 2020). To establish the credibility of the findings, I actively searched for elements that nuanced the emerging data and concepts by having 'negative case' buckets within NVivo (Miles et al., 2020). Moreover, I took steps to ensure that the participants considered the conclusions to accurately represent their perceptions (Miles et al., 2020). Once I had constructed a draft of the findings, I sent a summary to all 21 participants for validation and member-checking purposes. Two participants replied that they had no additional insights to be added to the findings. Last, as this thesis includes the participation of multiple stakeholders, I also signified throughout the findings where disagreements occurred between stakeholder groups.

Providing a thorough and context-rich description of the final thesis report also establishes the *transferability* of this study's findings. Specifically, the study characteristics have been described in detail (e.g., setting, participants, data processes, and findings). The report also specifies the limitations restricting the results from being transferred to different settings and contexts. To display the *application* of this thesis, the final report also contains a section describing the beneficiaries of this study (e.g., practice contributions).

Reflexivity

As the researcher responsible for data collection, acknowledging my personal biases is particularly important when reflecting on potential influences throughout the research process (Hennink et al., 2020). This includes the study's design, participant selection, data collection, and the subsequent interpretation and presentation of the data. In terms of my reflexivity, my research background involves working in technology-related initiatives in various healthcare settings, ranging from increasing access to pediatric specialty care to the long-term care sector. Additionally, I have a particular interest in exploring how health systems utilize and implement technologies for system improvement.

Starting July 11, 2022, I attended weekly virtual meetings with the CST team to immerse myself in the research setting and remain informed about COVID-19 processes at CHEO. I engaged in these meetings in a non-participatory capacity, and I was not involved in any

decision-making related to the contact tracing initiative. Although participants were aware of my upcoming research in this area, the information from these interactions did not contribute to any of the findings presented in this study. I stopped attending these meetings on January 2, 2023, as the CST was no longer meeting on a weekly basis. However, I was kept up to date with any changes related to the contact tracing process via email.

It is important to acknowledge that my experiences with immersing myself into the research setting and with my exploration of the literature on the use of different DCT approaches implemented during the pandemic, I did have certain expectations about how efficient, timely, and innovative this approach to contact tracing would be perceived. I also held an understanding that the DCT tool had been in use for most of the pandemic, leading me to assume that this approach had potential benefits for its continued use during the study period. However, I consciously made efforts to utilize this expertise objectively to minimize researcher bias. Therefore, the outcomes attributed to the DCT tool were allowed to emerge organically from the findings and insights shared by the participants.

In addition to the quality as presented in this section, strategies to reduce potential researcher biases included consistent documentation of processes, adhering to study protocol, and employing reflexivity. For instance, during data collection, interviews were designed to be unbiased and non-leading, ensuring probing questions did not steer participants toward particular responses (Hennink et al., 2020). Regarding reflexivity as the researcher, full immersion in the data occurred, involving thorough analysis, reflection on findings, and sufficient time devoted to examining codes, emergent categories, and themes. Furthermore, as recommended by Hennink et al. (2020), I actively made an effort to engage in negative case analysis to challenge and disconfirm emerging concepts.

Results

In this chapter, I present the findings from the qualitative analysis following the RE-AIM dimensions (discussed below). Within each section, I highlight the overall perspectives of implementors, occupational specialists, and end-users – describing the similarities and differences when present.

I begin by providing an overview of the study sample, including the different roles of participants within each stakeholder group. Next, I explore the concept of “Reach,” which

includes examining the intended audience of the DCT tool, as well as the individual-level considerations that influence engagement (e.g., barriers and facilitators). Following this, I present the findings related to the perceived "Effectiveness" of the DCT tool. I discuss stakeholders' perceived benefits of the DCT tool, including its scalability and agility in responding to the COVID-19 pandemic, the timeliness of the technology, and the impact at various decision-making levels. Within this section, I also report on the perceived challenges and unintended outcomes of the DCT tool.

Additionally, I highlight key indicators perceived by stakeholders to measure the effectiveness of DCT approaches within the hospital context. Under the "Adoption" dimension, I explore how the DCT tool was integrated into routine practices from an organizational perspective, including the facilitators, strategies to enhance its use, and the challenges encountered. Within the "Implementation" dimension, I present the key factors that influenced the implementation of the DCT tool and an overview of the implementation process. In the "Maintenance" section, I provide an overview of the various adaptations made to the DCT tool to ensure its consistent use throughout the pandemic. Additionally, I explore the perceived current sustainability of the DCT tool, as well as its post-pandemic use. In the final section, I present areas of improvement suggested by stakeholders.

Overview of Participants

Of the 27 individuals who had contacted me expressing interest in participating in the study, one individual declined participation due to a lack of experience with the DCT tool and five individuals were lost to nonresponse. This resulted in a retention rate of 78%, with the final study sample consisting of 21 participants. Table 3 displays the description along with the characteristics of the participants.

Table 3. Characteristics of the Study Sample

Stakeholder Groups	Description	No. of Participants Invited	No. of Interviews	Interviewees

Implementors[1]	Administrative personnel involved in conceptualizing/implementing the DCT tool.	6	6 (29%)	• 3 Managers • 2 Coordinators • 1 Vice President
Occupational Specialists	Occupational health and safety specialists who make decisions based on the data obtained from the DCT tool.	14	8 (38%)	• 1 Registered Safety Professional • 1 Physician • 1 Registered Practical Nurse • 5 Registered Nurses
End-users	End-users of the DCT tool.	66	7 (33%)	• 2 Physicians • 3 Registered Nurses • 1 Patient Service Clerk • 1 Family Resource Worker

Reach

For the "Reach" dimension, I focused on exploring the extent to which the DCT tool reached its intended target audience. Additionally, this included investigating the target audience's willingness to engage with the DCT tool, which involved understanding the factors that facilitated and hindered their engagement in the tool.

According to implementors and occupational specialists, the target population intended to use the DCT tool was all CHEO staff, including learners, volunteers, and medical staff who had possible exposure to COVID-19. Upon a staff member or patient testing COVID-19 positive, the tool was initiated and *"... targeted [to] those people [who] were working either within the same department, unit or around them" (P06, Implementor).* However, implementors and occupational specialists agreed that generally, the DCT tool was aimed at reaching the frontline medical staff. For the purpose of the results, the target audience of the DCT tool will be hereinafter referred to as "staff."

Facilitators to Engagement

Usability and Familiarity

Participants listed the facilitators that enabled better reach and engagement of the DCT tool within the hospital context. Several participants across stakeholder groups shared the

[1] Some participants in the implementor group had dual roles as occupational specialists. As they were identified as being heavily involved in the implementation process, they were considered part of the implementor stakeholder group for the purposes of this study.

perspective that the convenience and ease of using the DCT tool contributed to higher engagement among staff. Implementors and occupational specialists shared similar perspectives that the DCT tool reached and engaged staff, as it *"... captured a lot of information in an accessible way" (P06, Implementor).* Several implementors and occupational specialists also highlighted that staff adoption was likely influenced by the convenience of answering an electronic survey, as opposed to answering a phone call.

> "*For them to be able to respond quickly, virtually. Instead of having to respond to a call back and play phone tag back and forth with our team. It makes it easier for them as well." P05, Occupational Specialist*

Many implementors and end-users also expressed that they found the DCT tool to be *"intuitive"* and *"straightforward,"* respectively. Additionally, many end-users acknowledged their preference for the DCT tool, as they tend to be unresponsive to phone calls.

> *"It worked out for me because I am not really good at answering my phone. ... The fact that it was emailed to me and that the questions were very brief, they were quick. That was pretty easy." P13, End-user*

Facilitators to staff adoption also included the belief that the DCT tool was easy to learn to use and operate. Few end-users recognized that after receiving guidance on how to use the DCT tool, they valued its user-friendliness. While participants across stakeholder groups acknowledged the *"transient"* workforce of the hospital in terms of varying education levels, age ranges, and technology comfortability, the DCT tool was still largely perceived as easy to use.

> *"I work with a lot of, at that point when I was (...) during the real pandemic when it first started. I was in ICU when we had idled COVID patients. And what I loved about it is, our senior nurses, which can't stand anything technology-based, we're like, 'it's so easy to navigate.'" P18, End-user*

A few end-users noted that this functionality decreased the requirement for staff to utilize a computer to complete the DCT tool. End-users perceived this to make the DCT tool more accessible, as it could be readily available through mobile phones.

> *"REDCap is pretty good with adjusting to a mobile device. So, it was easy to fill out, I did it on my phone. I didn't have to log into a physical computer." P14, End-user*

Additionally, end-users valued the functionality of the comment box within the DCT tool. End-users expressed that the ability to offer additional details on their exposure, which might not

have been accurately captured by the risk-assessment questions, enhanced their engagement as they could provide additional information that would subsequently impact their work status. Similarly, a small number of implementors also acknowledged that the comment section gave staff an *"opportunity"* to elaborate on their exposures and provide additional context for the CST that may have not been captured in the questions asked.

> *"The answers were prompted, and the comments section was also very useful. Because even though our answers made it seem like we came into direct contact with the patient, it was always for less than two minutes or less than five minutes. And that made the entire difference, between us having to stay home for 10 days as a precaution or continuing to work." P17, End-User*

Implementors and occupational specialists also perceived that staff's engagement with the tool was increased partly due to their familiarity with using similar processes in the hospital for aspects of COVID-19 monitoring, such as entrance screening. One participant perceived that a contributor to the *"success"* of the DCT tool was *"... building that familiarity and consistency with the [staff]" (P05, Occupational Specialist).*

> *"I think it made a nice little bucket for them to just accept [that] this is how we're going to do our COVID contact tracing, screening, and everything." P06, Implementor*

Self-awareness and Safety Practices

A few implementors and occupational specialists expressed that collectively, there was a widespread sense of fear and uncertainty within the healthcare environment at the onset of COVID-19. These participants suggested that, because of this fear, staff were especially concerned about their safety given the nature of their frontline roles. Consequently, this fear led staff to actively seek out information and reassurance regarding their potential exposures, which was communicated through the DCT tool.

> *"Fear. People wanting to know if they've been exposed and wanting to know what to do if they had been exposed early on." P12, Implementor*

> *"It was unknown, there was a bit of a fear factor involved with COVID when it first started. Everybody wanted to know whether or not they were safe." P11, Occupational Specialist*

However, the perspective that fear of COVID-19 played a role in encouraging their staff's use of the DCT tool was not expressed by end users. Instead, end users themselves shared common perspectives that the desire to gain awareness regarding COVID-19 exposure as a

means to safeguard the well-being of those around them, including both their personal lives and working environment, contributed to their engagement with the DCT tool.

> *"I had to use the tool in order to ensure the safety of the people I was in contact with. Just to make sure there wasn't any incidental or non-incidental contact traces that put some people in high-risk factors." P13, End-user*

> *"So, I was the runner during the pandemic. And I wanted to make sure that it wasn't bringing home to my parents." P17, End-user*

In line with this, several implementors and occupational specialists also reported that staff's engagement with the DCT tool was also driven by the *"professional accountability"* of staff. One implementor stated that *"... people who are professional and dedicated healthcare workers, [they] worry about their patients and would not want to inadvertently transmit something to their patients" (P07, Implementor).* Consistent with this perspective, several participants cited that staff's use of the DCT tool was facilitated by the presence of working within a children's hospital.

> *"I feel like most of our employees, because we work at a children's hospital. You kind of want to be aware of if you were in contact with a contact, who is now at work and working with a patient." P06, Implementor*

> *"We're still at the highest level of alert. It is peds, man. You can't, you know? Not that anyone should get COVID and die, but I'm just saying. We want to protect our population." P15, Occupational Specialist*

Last, an end-user also emphasized the distinctiveness of delivering a DCT tool specifically within the hospital environment. This participant highlighted that upon receiving the DCT tool, they were not only engaged by their motivation to maintain safety standards but also by being held accountable through the follow-up mechanisms the hospital had in place (e.g., CST).

> *"... And I know that I work at CHEO, and it's pretty easy, right? I'm in a setting where I get a tool delivered, and I can answer it, and I help the organization track. But I also know that if I didn't do that, people could follow up with me." P01, End-user*

Barriers to Engagement

Accessibility and Support

Despite being initially unaware of the DCT tool, many of the end-users cited that they did not face many barriers to its use. However, a few end-users and other stakeholders noted that the DCT tool was distributed in ways that required specific resources and skills for its use. One end-

user cited that their initiation of the DCT tool was made possible through personal contacts, and the absence of this connection could pose challenges for some. Additionally, this end-user noted that with the transition to *"passive screening,"* the DCT tool lacks intuitiveness regarding when staff are required to complete it.

> *"The only thing that was, I tested positive post being at CHEO. So, the initiation of the tool was more or less because I know somebody on the contact tracing team. So, it's a bit different. … I guess I would have emailed the occ[upational] health. It's just that delay piece of the timing of it, especially now going to passive tracing. There isn't necessarily the intuitive notion that you should fill the form if you test positive type thing." P14, End-user*

Participants also suggested that potential difficulties existed for the technology required to complete the DCT tool, including staff access to smartphones and devices. In addition to end-users noting this, a few implementors and occupational specialists identified that "*… a small minority of staff [did not] have cell phones" (P02, Implementor).*

> *"If you're not inclined to have a smartphone, then obviously you can't access it from there." P14 End-user.*

Furthermore, a few participants also noted potential language and literacy barriers with the DCT tool. For example, one implementor reflected on their past experiences related to training individuals on hospital policies, suggesting that some staff may have encountered difficulties in understanding the language of the DCT tool if their first language was not English or French. Second, occupational specialists also highlighted that the DCT tool contained some unfamiliar and complex contact tracing terminology, which may have also impeded engagement.

> *"There could be people on certain teams that don't read English. I don't know that, but I would throw that out there. We have had that worry when we try to train people on policies and environmental services. For example, we had some concerns in the past that there could have been some of the older ES [environmental service] staff that maybe didn't read English." P07, Implementor*

> *"We did receive feedback at some point that when we were trying to screen volunteers and do a risk assessment on volunteers, they didn't understand the lingo." P11, Occupational Specialist*

Implementors and occupational specialists discussed the strategies used to overcome access barriers. For instance, when staff faced challenges in accessing or completing the DCT tool, the CST was available to provide support via phone calls. Moreover, occupational

specialists also mentioned that paper copies of the risk-assessment survey were available on-site when needed.

> *"… We give them a phone call and then help navigate them. Sometimes people had to be helped navigate through these questionnaires. I think that can be a barrier. That as much as we are technology, moving forward society, we forget that there's still some people that do not have technology, right? So, the accessibility. But we had people, like I said, seven days a week, we still had people that can help navigate them." P15, Occupational Specialist*

Concerns of Risk Assessment

As noted by several participants across stakeholder groups, the DCT tool was *"... based on an honor system" (P19, Occupational Specialist)*, as staff were aware of the implications of providing truthful responses within the risk-assessment. Several participants suggested that the staff's inclination to fully engage with the DCT tool may have been hindered by their *"hesitancy"* to report potential breaches or COVID-related systems due to perceived negative outcomes, such as being temporarily removed from work. An implementor also noted that staff may have not had a clear understanding of why they were questioned on their adherence to guidelines and interactions.

> *"Some people might not have understood even, why? Why would you? Why are you asking all these questions about me? People could have been suspicious to say, 'Well are you asking me these questions because you want to see if I did something wrong? You want me to say that I didn't wash my hands, or I didn't wear my PPE when I was in proximity? Are you trying to get me in trouble?'" P07, Implementor*

An end-user also noted that staff may have been concerned about potential breaches of confidential information. However, it is important to note that while no end-users cited that these factors acted as barriers to their utilization of the DCT tool, they expected such barriers to be present among others.

> *"I guess, if I put on somebody else's shoes and think about what they might feel, maybe they worry about breach of confidentiality. Maybe they worry about identifying themselves as not having utilized all the equipment that they were supposed to be using in the room at the time or with a particular colleague. And that might put them out of work, right?" P01, End-user*

Reach Summary

It was agreed upon by most participants that the DCT tool was directed to all CHEO staff, including learners and volunteers. However, participants did note that the DCT tool was

primarily targeted toward frontline medical staff, as their roles most frequently exposed them to COVID-19. Participants across all stakeholder groups acknowledged that staff's engagement with the DCT tool was primarily due to the convenience and ease of using the technology. Some implementors and occupational specialists also perceived that staff's familiarity with the platform (e.g., through daily entrance screening) also encouraged staff's engagement with the DCT tool. Several end users noted that their engagement with the DCT tool was facilitated by their desire to gain self-awareness regarding COVID-19 exposure as well as their commitment to safety practices. Participants also highlighted that staff's professional accountability increased engagement with the DCT, particularly in the case of a pediatric hospital. Additionally, an end-user highlighted the influence of the technology being delivered in the hospital setting, noting the presence of direct follow-up.

Many participants did not encounter many barriers to engaging with the DCT tool. Nonetheless, a shared opinion was that the distribution of the DCT necessitated staff to have the appropriate resources and skills to successfully utilize the technology. While no end-users personally experienced these as barriers, participants among the stakeholder groups acknowledged that the DCT tool was largely based on the ability to complete the survey on a mobile device. Furthermore, it was recognized that some users of the DCT tool may have had barriers to understanding the language and terminology. Last, participants also highlighted that barriers may have arisen from staff's privacy concerns and their perceived negative consequences of the DCT tool. Table 4 provides a summary of the key factors related to staff facilitators and barriers to staff engagement with the DCT tool.

Table 4. Facilitators and Barriers to Reach

Theme	Description
Facilitators	
Usability and Familiarity	• Connivence of answering survey rather than phone call • Familiarity with the DCT tool from entrance screen and frequent usage • User-friendliness of the technology • Ability to adjust to mobile devices
Self-awareness and Safety Practices	• Fear of COVID-19 • Workplace and personal transmission • Responsibility and accountability

	• Vulnerable patent population • DCT tool delivery in a hospital setting
	Barriers
Accessibility and Support	• Initiation of tool • Accessibility issues—technology proficiency, access to cell phones/email-equipped phones • Language and terminology
Concerns of Risk Assessment	• Consequences—temporary work status or perceived repercussions • Breach of confidentiality

Effectiveness

Under "Effectiveness," I explored participants' perceived effectiveness of the DCT tool. Namely, this included discussing stakeholders' perceived benefits of the DCT tool, alongside its challenges and unintended outcomes. Additionally, participants shared key indicators to measure the effectiveness of DCT strategies within the hospital context.

Perceived Benefits of Digital Contact Tracing

Agile Response to COVID-19

There was overwhelming agreement between implementors and occupational specialists that the pandemic necessitated rapid changes to be made within the hospital, including surveillance policies and procedures. Implementors and occupational specialists spoke extensively about how the guidance on case and contact management was *"forever changing."* Furthermore, many of these participants highlighted that the DCT tool offered an *"adaptable"* response to COVID-19 based on its ability to easily evolve *"... with new guidelines and new requirements" (P19, Occupational Specialist).* Furthermore, participants noted that the DCT tool alleviated the need to *"start from scratch*" following these updates, as the necessary modifications could be easily integrated into the existing format.

> *"We were basically just tweaking our tool. It was always, 'Let's review this information that's provided from the provincial guidance' and cross-reference it to our decision tree, and then confirm whether or not we had to make changes, and what changes needed to occur. If we needed new alerts, or if it was just a matter of changing, or adding more information to our current alerts." P02, Implementor*

> *"That whole process of updating, and then notifying the nurses who had to then go in and access these documents, that was eliminated. You could just update your REDCap tool, whether it was on a weekly basis, because that's how quickly how frequently the guidance was changing. Or on a monthly, or every few months' time." P09, Occupational Specialist*

Another key concept emphasized by many of the implementors, and occupational specialists was that the DCT enabled the CST to adapt to the necessary COVID-19-related changes without overstretching their resources. For instance, one participant expressed that the DCT approach *"... alleviated a lot of the tedious phone calls that would need to be made for contact tracing" (P05 Occupational Specialist).* Participants among all stakeholder groups recognized that the DCT tool alleviated the burden of tedious tasks for the CST, which enabled them to utilize their skills to have a *"... more meaningful [and] better impact from a human interaction perspective" (P13, End-user).*

> *"Our initial exposure investigations involved, dozens to hundreds of healthcare workers. You're trying to do a phone call to ask the same questions, I think that would have been so inefficient and not a good use of the skills and expertise that the occ[upational] safety nurses have." P09, Occupational Special*

Implementors and occupational specialists also highlighted that the DCT tool expanded the hospital's capacity to accommodate contact tracing even during periods of heightened transmissibility, particularly during the Omicron variant. Instead of being completely overwhelmed and not having the capacity to respond to the high rates of infection, one occupational specialist expressed that the technology also proved the adaptability of the DCT tool and its usefulness in this scenario.

> *"It helped relieve the stress of a lot of stuff. Especially, when we were in the acute phase of it, which lasted a very long time. Because as soon as we came off the down, Omicron hit. We were able to adapt very efficiently kind of you know, doing a little dance. It wasn't a panic, we just moved into that next step by altering some of the stuff on the survey." P11, Occupational Specialist*

One implementor reinforced this perspective by contrasting the DCT tool with Ottawa Public Health's traditional contact tracing approach. During surging periods, it was noted that public health could not sustain the identification of high-risk individuals in the community. However, as the volume of staff with COVID-19 increased, it was attributed that the established DCT approach enabled the hospital to continue large-scale case investigations.

> *"There's no way that we would have survived subsequent terrible waves, had we not had a process like this in place. So, then it would be like public health where you think, 'Well, we give up. We just can't do it anymore.' Which isn't okay." P03, Implementor*

By automating various "*alerts and notifications,"* implementors and occupational specialists noted that the necessity for numerous *"touch points"* between staff and the CST was reduced. This prompted a reduced need for the hospital to allocate an extensive amount of HHR for contact tracing. In contrast to the HHR required to complete traditional contact tracing, implementors valued the *"cost efficiencies"* stemming from the DCT approach, as the CST primarily ranged from four to six nurses. Furthermore, an occupational specialist noted that the hospital is a *"24/7 business"* that was operating with *"... not a lot of reserves" (P15, Occupational Specialist)* throughout the COVID-19 pandemic. Considering this perspective, the DCT tool was also viewed as a means to optimize HHR during a crisis scenario.

> *"And then of course, the organization benefited financially, in the sense that we didn't have to staff. We didn't have to have 20 or more COVID nurses. Or do this as a manual process, right?" P02, Implementor*

Timely and Broad Reach

Several participants among the stakeholder groups acknowledged the timeliness of the DCT, which benefited both the CST and the staff. Many implementors and occupational specialists shared the view that once staff were identified as a potential high-risk contact, the email delivery of the DCT tool facilitated a prompt and simultaneous reach. This was highlighted as a key outcome, given the time-sensitive nature of contact tracing and the high volume of COVID-19 cases.

> *"There's no way, if you had to contact trace 50 people. If you were going to make phone calls and do that manually. It would have taken you weeks to complete. But we were able to do that within a day, right? You just enter the emails into the system and within a day, you have an email sent and potentially quite a few responses back?" P02, Implementor*

Participants also recognized the timely impacts of the DCT tool among staff. From the perspective of implementors, the DCT tool provided staff with *"... 'just-in-time' information and guidance" (P02, Implementor).* It was also noted that the algorithms embedded within the DCT tool provided staff with detailed guidance and the next steps to take, including whether testing was necessary, where to get testing, isolation requirements, and return to work protocols.

> *"We would get to people sooner, the algorithm worked. We were able to say, 'Do this, do this if you've had contact.' Instead of having to wait to contact someone by phone, maybe two days later or three days later, they would get an email response right back and it would go through the algorithm and whatnot." P04, Implementor*

The concept of a timely reach also gained additional backing from numerous end-users, who perceived that a primary benefit of the DCT tool was its ability to provide them with *"quick"* and *"reliable"* guidance after being exposed to COVID-19. End-users also drew a comparison to the traditional approach of contact tracing employed by the hospital before the implementation of the DCT tool. They conveyed that initially, the delays in timing as to whether they had been exposed to COVID-19 evoked feelings of uncertainty. Given these outcomes, end-users widely regarded receiving timely guidance as a positive outcome of the DCT tool.

> *"It was quick. It would tell me what my next steps were. Whereas in the paper form, it was like, 'Someone will get back to you within 24 hours.' So, you might be sitting there spreading everything, but you don't know, right? What your next steps were supposed to be. That's why I think it was so beneficial." P18, End-User*

Implementors and occupational specialists also expressed an overall positive outlook on the *"heightened efficiencies"* related to the DCT tool, specifically by promptly reaching staff and facilitating thorough case investigations. By leveraging technology, implementors and occupational specialists pointed out that not only could the CST complete contact tracing within the *"required timeframe,"* but the DCT tool also facilitated their ability to contact tracing all probable individuals.

> *"I think we definitely were able to capture more people than any other hospitals within each contact tracing exercise we had, for sure. And initially, we were really thorough doing that. Like, 'Okay, this patient was positive in emerg, 47 people saw them [on] these days.' Plus, we would go into nursing students that were on the floor, or if there was an RT [Respiratory Therapist] student that was with another RT. We were super thorough, and then we were able to capture everyone." P21, Occupational Specialist*

Informed Decision Making

Several participants across stakeholder groups also emphasized the capability to gather data and subsequently guide evidence-based decision-making as another key outcome of the DCT tool. Participants acknowledged that the DCT tool facilitated a "*reproducible measure"* that could be *"... consistently applied across the organization" (P09, Occupational Specialist*). From this perspective, participants perceived that access to real-time data had dual impacts.

These data facilitated informed decision-making not only at the organizational level but also at the individual level. At the organizational level, implementors and occupational specialists shared perspectives that analyzing the data within the DCT tool was instrumental in tracing transmissions and aiding in the determination of whether COVID-19 cases were acquired by the hospital.

> *"For contact tracing, we were able to go back and determine whether there may have been a potential exposure related to surveys that were filled out and kind of map everything together. If we were trying to figure out if there was a transmission within the hospital." P11, Occupational Specialist*

Furthermore, implementors and occupational specialists noted that data-driven insights related to the dynamics of transmission were facilitated by the DCT tool. These participants highlighted that extracting data from the DCT tool allowed hospital leaders to make informed decisions on COVID-19 policies and procedures with *"relative confidence.*" Furthermore, participants shared the perspective that one of the main contributions of the tool was its impact on the hospital's *"safety culture."*

> *"I think the tool was so successful with the contact tracing. It was because we were really able to drill down some of the different reasons. … I think it also, organizationally, gave us a great idea of where 30% of the cases that turned positive, [it was] because those people had a breach in their PPE, or they didn't wear PPE. Or, you know, this and that." P06, Implementor*

At the individual level, participants across stakeholder groups collectively voiced the viewpoint that awareness of COVID-19 exposure influenced staff behavior, both within the workplace and in their personal lives. Few end users highlighted that the DCT tool enabled them to recognize when they were at heightened risk for COVID-19. In this regard, the DCT tool was perceived as a means of delivering education, as it facilitated staff recognition of COVID-19 exposure

> *"So, then going through the questionnaire kind of made you realize, 'Oh, I'm okay. I'm completely okay. Or maybe I need to sit this one out.'" P17, End-user*

> *"It just helps you sort of make the decision, like, 'okay, I was a high risk. And I meet these criteria, and I will be sent the next steps for me to do.' Or 'I wasn't there for very long. I don't think.' It helps you make your own decision and in your own risk assessment, I feel." P20, End-User*

Many participants across stakeholder groups shared the perspective that staff being made aware of their exposures through the DCT tool had extended safety impacts. Participants acknowledged that the supplementary benefits of the DCT tool included staff being more aware of their behaviors and practices (e.g., PPE). In turn, this created a "… *safety zone for patients" (P16 End-user)* and their families.

> *"If you're working in neonates (…) working in work self-isolation, you have a greater understanding and heightened awareness. That, 'I've been in contact with COVID, I need to monitor my symptoms for 10 days.' So, it's a heightened awareness of keeping your PPE proper. You should always keep it proper, and you should never breach it. But it keeps you that more aware. Because now you could impact that little 24-weeker."*

Overall, many participants across the stakeholder groups perceived that the DCT tool was evidence of the hospital's commitment to upholding a standard of collective safety and reducing this rate of transmission not only in the hospital but also in the broader community.

> *"One, the patient. Two, the families. Three, the staff. And four, our community. Because we are saying that we are a safe environment, we have these measures in place. But not only are we saying it, but we're using tools in order to prove that we have those measures in place." P16 End-user*

> *"It was the safety of the staff, of the families that we work with, of the patients. I think it was most important to keep everybody safe. I truly believe and I really believe that it did help, because of it." P18, End-user*

> *"Because then [staff are] aware, 'I've been in contact. So, if I get a runny nose. Well, that may not just be a runny nose.' So, then it helps reduce the spread. You can say the employer. The community, because we're not going to be (…) you've been in contact with COVID at work. Now, you're not going to be going out there spreading it to long-term care, spreading it to immunocompromised people, because now you're aware that you've been in contact." P15, Occupational Specialist*

As a result of having access to real-time data and an improved culture of safety, the DCT tool was also noted for its positive outcome of having *"... really good control about COVID spread" (P05, Occupational Specialist*). In this instance, several implementors and occupational specialists expressed the shared belief that these factors contributed to the hospital achieving the highest safety performance in the region, which was characterized by a limited number of hospital-acquired outbreaks among staff and patients.

> "*… If you look at the number of outbreaks and everything like that. That's the number one "why" we kept it at CHEO. That tool was able to help keep CHEO safe from COVID and*

have the best COVID safety record in the region. So, I think that's huge. What we did worked." P19, Occupational Specialist

"Because we would get reports when there's outbreaks and CHEO had the lowest, right? So, at least that's what senior management says, that we were the lowest, one of the lowest. That really shows that keeping these measures did help protect our workforce and also protect the patients." P15, Occupational Specialist

While most of the participants across stakeholder groups highlighted the favorable safety impact of the DCT tool, a few also acknowledged that this outcome was not exclusively an outcome of the tool itself. Rather, participants highlighted the *"magnitude"* impact of other COVID-19 prevention measures employed by the hospital, including universal PPE requirements, distancing measures, mandatory entrance screening, and the accessibility of testing for staff. In this regard, the DCT tool was just one mitigation among others, that provided "… *layers of protection" (P09, Occupational Specialist)* to ensure staff and patient safety.

"I think that it works, what we did was working. And plus, it's not only the contact tracing tool. But there were also other mitigations that we had in place. Our screening was very intense. Our masking, everything was." P19, Occupational Specialist

A less common perspective was that the hospitals' use of multilayered mitigation, such as the policies regarding self-isolation when feeling symptomatic, was more beneficial for maintaining COVID-19 transmission than the DCT tool.

"I don't know how beneficial it is. Because again, if you're sick, you stay home. We are all wearing masks. So, even if you were a high-risk exposure, the risk is very low. So, contact tracing. (…) We have other parameters in place." P10, Occupational Specialist

Challenges and Unintended Outcomes

Technology Limitations

A few implementors and end-users raised concerns regarding the digital approach to contact tracing, as it relied on the assumption that staff were receiving the link to the DCT tool. An implementor highlighted that if there were staff members who never checked their emails, this approach may have *"inadvertently"* led to ignoring a subgroup of staff. One end-user also expressed concerns related to organizational emails, mentioning that an email could mistakenly be sent to spam or the potential for the email system to *"divert"* the email. In combination, these factors highlight some limitations related to relying on email to initiate the DCT tool.

"And if it's someone who never checks their email. Well, they didn't see the first time, they're not going to see you that follow-up either. So, I suppose that could have been like a little pocket of people who might just essentially have not been communicated with at all." P03, Implementor

Many participants across stakeholder groups also voiced concern regarding platform suitability and questioned whether it was the most appropriate tool to deliver electronic risk assessments. First, a few implementors and occupational specialists highlighted the issues with multiple free-text fields that were embedded in the DCT tool. They noted that this may have led to incomplete or inaccurate data being captured in the DCT tool. Similarly, participants also highlighted that when users incorrectly typed free-text fields, this resulted in staff not receiving subsequent guidance and consequently affected the overall impact of the DCT approach.

"… It asks [for] your email, and it asks for your manager or supervisor's email. The only way to have those populated, is that you manually have to type in that field. So, if you type in that field wrong, it's automatically not going to send. You don't get another chance to go back in and edit it, you can't go back in and edit that you had said your email wrong. So, you're never going to get that bounce-back email to you about what to do next and yada." P06, Implementor

Implementors and occupational specialists also suggested that utilizing the same platform for both electronic screening and contact tracing led to the server being overutilized. On occasions, this resulted in creating new links to the tool, which participants cited often caused confusion among staff when accessing the survey. For instance, end-users expressed that they had *"… had a hard time finding the link" (P20, End-user),* attributing it to the CST changing the link to the DCT tool.

"The other issue encountered was that there were so many forms being completed, whether it be entrance screening notifications and contact tracing forms being completed, that it would slow down REDCap. So, there were a few points in time, we had to either purge the data and save it somewhere else, or we'd have to create a new link, a new REDCap link." P02, Implementor

By removing the interactive element of contact tracing (e.g., phone interviews), many implementors and occupational specialists also noted that this posed challenges during case investigations as *"nuanced"* information was lost. This included the CST's ability to probe staff on their exposures, ask follow-up questions, or clarify answers. Instead, with the digital approach, the CST was limited to interpreting what staff had submitted within the DCT tool.

"I think that's probably the biggest challenge is that [with] us interpreting it, we don't always get the best picture. Or as clear of pictures as we would have been able to get verbally." P05, Occupational Specialist

"… There is recognition that you could be face-to-face with someone, and they're not masked. Versus face-to-face with a mask, versus at the back of the room, or at the foot of the bed, or talking to them at the door." P09, Occupational Specialist

Several occupational specialists also outlined scenarios in which the case investigation process (e.g., EMR review and line lists) would not capture all personnel who may have had a potential exposure to the positive case. It was acknowledged that the CST relied on staff to provide additional information on the potential exposure within the tool's embedded comment boxes. Nonetheless, this approach necessitated staff identifying those who may have been potentially in the room or involved with the patient's care during the period of communicability. One end-user expressed that in their circumstance of completing the DCT tool, they identified one individual who potentially had exposure to the positive case. However, as a result of not having sufficient "… *personal health information" (P13, End-user)*, they were unable to accurately record all potential exposures in the tool.

"But, in the contact tracing survey, it does just say, 'Is there anyone else that we might have missed?' So, then that will trigger people to then go ahead and say, 'Yes, you missed [(Name)] who came in and held the patient,' right? You would have never documented that because you just came in and held. So, unless the nurse wrote that you held, we would never have an idea that that person was in the room unless a physical person could tell me that." P15, Occupational Specialist

Some implementors and occupational specialists also expressed the difficulties related to asking staff to recall information about their exposures with patients and colleagues several days after the possible interaction. Namely, this introduced its limitations for accurately capturing the dynamics of possible transmission.

"Sometimes [the] clinical staff were being notified three or four days after their shift. They were like, 'Which one of the five kids? Or, the additional two that I covered for my colleague? I can't remember which one you're talking about.' Or 'Yeah, they were 12. But were they masked every time? I don't know, because I wasn't asking them to mask every time I went to see them.' Or 'Did I go close to their face for a prolonged period of time? I don't know.'" P09, Occupational Specialist

Last, occupational specialists also highlighted that additional follow-up steps were necessitated upon staff submitting their DCT tool. A few occupational specialists believed that in

certain situations, these extensive follow-up procedures were *"unnecessary"* and were frequently more *"time-consuming".*

> *"If we were bordering between, one little question, whether they had a mask on or not. It would be the difference between the mask on. But distance, let's say, or did they have eye protection? Yes, we knew they had a mask. But did they have eye protection on? Where it was maybe that one word might have been off, and we would have to follow up." P11, Occupational Specialist*

Staffing Impacts

Negative implications of the DCT tool were infrequently mentioned; however, a few participants among the stakeholder groups did consider the impacts on staffing. In addition to HCWs being identified as high-risk exposure to COVID-19, a few occupational specialists and end users highlighted that staffing capacity challenges were experienced during COVID-19 because of *"deferred retirements."* They noted that at certain points in the pandemic, the case and contact guidance from the MOHLTC limited staff from working after being identified as a high-risk exposure. This led to staff being furloughed for up to 10 days based on their exposure or longer if they had contracted COVID-19 during their self-isolation period. Subsequently, this challenged the hospital's capacity to provide care for patients, as the initial guidelines followed could result in staff being furloughed for more than 14 days.

> *"They're off for five days or four days, and then they got COVID. Then, they were out for another 10 days. So, that put the unit out two weeks from medical staff or other staff." P09, Occupational Specialist*

Another occupational specialist also highlighted that even before the onset of the pandemic, frontline HCWs were already under strain from working in a healthcare system with increasing demands. Furthermore, they expressed that the implications of furloughing frontline staff were of greater concern in terms of the capacity to care for patients, considering the already heightened stress.

> *"… And then, it would impact the [patients] negatively. Because then it would be, if we had to isolate staff, they couldn't come into work. Then, there was no staff to take care of the patients. Were short-staffed already, in an already stretched healthcare system." P19, Occupational Specialist*

> *"Let's say an office worker was a high-risk exposure. Well, that's not really affecting the patients. But the frontline staff, it really affected, because they had to be off and all that." P10, Occupational Specialist*

Indicators of Effectiveness

Under the "Effectiveness" dimension, I also investigated participants' perspectives on how to assess the effectiveness of DCT approaches within a hospital context. The aim of doing this was to provide benchmarking evidence by developing a set of perceived high-impact indicators that can inform future DCT practice improvements and measurability. It is worth noting that many of the metrics presented below are from the perspective of implementors and occupational specialists. When end-users were asked how they would gauge the effectiveness of DCT approaches, they had limited or no comments to provide. This may be a result of end-users' limited experiences using the DCT tool or insight into the DCT process itself.

Responsiveness and Engagement

Participants identified a diverse set of indicators for assessing the effectiveness of DCTs. First, several participants across the stakeholder groups perceived that assessing the timing of responses and staff engagement was imperative when evaluating a digital approach to contact tracing. Specifically, participants expressed that assessing the ability of the technology to be distributed and the speed at which it is delivered to the intended audience are noteworthy aspects.

> *"Well, so, it has to reach the person. I mean, effectively, it should be 100% of the time. But it has to sort of have a high incidence of reaching the person. And it has to reach the person in a timely manner so that it actually makes a difference." P01, End-user*

Nonetheless, considering the time-sensitive nature of contact tracing, a few participants also expressed that determining the target audience's response time would be an essential metric.

> *"If the goal of the enhanced contact tracing tool is to efficiently identify all possible staff exposures, then, it'd be great to know the timing. How quickly are they identified? How quickly are they fill it out? How thoroughly is the follow-up? If we had 100 exposures, and they were historically phoned, what was the timeline to the end? How much time did it take to do that, versus 100 staff identified through the contact tracing tool? Then, their responses come in within X number of hours, or days, there's that piece." P09, Occupational Specialist*

In line with the above, an occupational specialist also expressed that evaluating the timeline of case investigations with DCT approaches compared to traditional contact tracing would be an essential indicator.

"If we had 100 exposures, and they were historically phoned, what was the timeline to the end? How much time did it take to do that, versus 100 staff identified through the contact tracing tool?" P09, Occupational Specialist

A unique perspective significance noted by an implementor was assessing staff's satisfaction with a DCT approach and their confidence regarding the hospitals' mechanisms to assure safety.

"Staff satisfaction would be a big one. Just the fact, do people feel safe coming to work and did the tool help them feel safe coming to work?" P12, Implementor

Infection Management

Participants emphasized the importance of measuring a range of metrics to evaluate the effectiveness of a DCT approach and its subsequent impacts on disease prevention within the hospital context. These indicators are further detailed in Table 5.

Table 5. Infection Management Indicators

Indicator	Description	Quote
Symptom Management	Assessing whether a digital approach enabled staff to monitor their COVID-19 related symptoms and subsequently reduced further transmission.	"If cases were picked up because of it. So, you were a *high-risk exposure*, therefore, you were *more carefully tracking your symptoms*. Therefore, you *identified a symptom more quickly* and *didn't end up coming to work because you were sick*. Versus, if you hadn't done the contact tracing, you wouldn't have been quite as careful and may have exposed others. Some *type of thing to identify transmissions and track those*." P12, Implementor
Outbreak Prevention	Determining if DCT reduces COVID-19 cases and outbreaks.	"I think the first thing is, if you look at the *number of outbreaks* and everything like that." P19, Occupational Specialist
Risk Mitigations	Evaluating if a DCT approach enhances or reduces safety mitigations or risks within the hospital.	"And if it *reduces further exposure* or *heightens the level of positive or weakness towards certain measures* that are already taking place. Then obviously, if it does its job in terms of measuring some *level of risk*." P14, End-User

Accuracy of Risk-Assessment	Assessing the extent to which the DCT approach provides reliable and precise results for identifying high-risk staff. - Includes determining how frequently additional verification was needed to confirm additional information that was not provided in the DCT approach.	"We do work self-isolation now, but before, we would have isolated, whether they actually contracted COVID? To know *the accuracy of the assessment* and the determination of high risk, is at least somewhat linked to the real risk." P05, Occupational Specialist
Patient Impacts	Evaluating if the DCT approach reduced COVID-19 impacts on the patient population or any patient related outcomes.	"If it *decreased the impact towards* obviously, the *patient population*. As well as any patient impacts." P14, End-user

Technical Operations

The last key measure that participants considered would be important when assessing a DCT approach's effectiveness was technology operations. One implementor perceived that the capabilities of the technology used in a DCT approach should be *"…nimble in terms of modifications" (P03, Implementor)*. Furthermore, a few occupational specialists and end users expressed the need to assess the user-friendliness of technologies used in DCT solutions. One participant indicated that the technology should have *"... very few options you need to click through" (P13, End-user).* This concept was further highlighted by an end-user who stated:

> *"… Those decision algorithms, as to sort of what happens with the result of that contact tracing tool. That has to be quite clear and transparent, right?" P01, End-user*

A few implementors also perceived the capabilities of a DCT platform to securely store and share data as per the needs of requirements as another key factor of consideration.

> *"To be able to look for the current state. So again, at IMT and at the board, we would report, 'We have X patients positive in the hospital, we have Y staff, and one of those staff may be because of a patient exposure.' So, having that data available as requested by the Ministry would be a very important evaluation." P12, Implementor*

Effectiveness Summary

In summary, participants across the stakeholder groups recognized the positive outcomes of the DCT tool over traditional approaches, particularly appreciating its scalability and

flexibility in meeting the evolving requirements imposed on health systems during the pandemic. However, implementors and occupational specialists provided deeper insights into the operational benefits, such as its role in accommodating contact tracing during periods of heightened transmissibility, streamlining processes, and optimizing HHR. Nonetheless, participants from all stakeholder groups acknowledged that the DCT tool improved the speed of reaching and informing staff on the follow-up steps after being exposed to the virus. As a result, many participants held the view that the DCT tool enhanced safety beyond the staff, extending to patients and their caregivers. There was also a consensus among stakeholders regarding the DCT tool's positive impact on decision-making, including at both the individual and organizational levels. For instance, end-users noted a benefit was their enhanced comprehension and awareness of COVID-19 processes. While challenges and negative consequences were less frequently mentioned, some implementors and occupational specialists noted the DCT tool's role in staffing implications.

Additionally, participants expressed challenges with the platform utilized and identified limitations of the technology. Namely, this included issues related to the DCT tool's server capacity, manual requirements, issues related to recall limitations, and the tool's inability to capture nuanced information. Fig. 3 demonstrates an overview of participants' perceived outcomes and impacts, stratified by stakeholder group.

Furthermore, this section also provides a comprehensive list of participants' perceived key indicators for the effectiveness of DCT approaches. The majority of the indicators noted by participants were related to assessing the performance of DCT in managing infection, including evaluating its role in monitoring symptoms, outbreak prevention, risk mitigations, and patient impacts. Nonetheless, participants also identified assessing the flexibility and ability of the technology to meet the needs of the organization as essential indicators. From a user perspective, evaluating staff satisfaction and confidence with DCT approaches should be considered, alongside its outcome of being user friendless. A general summary of the indicators provided by participants can be found in Appendix E.

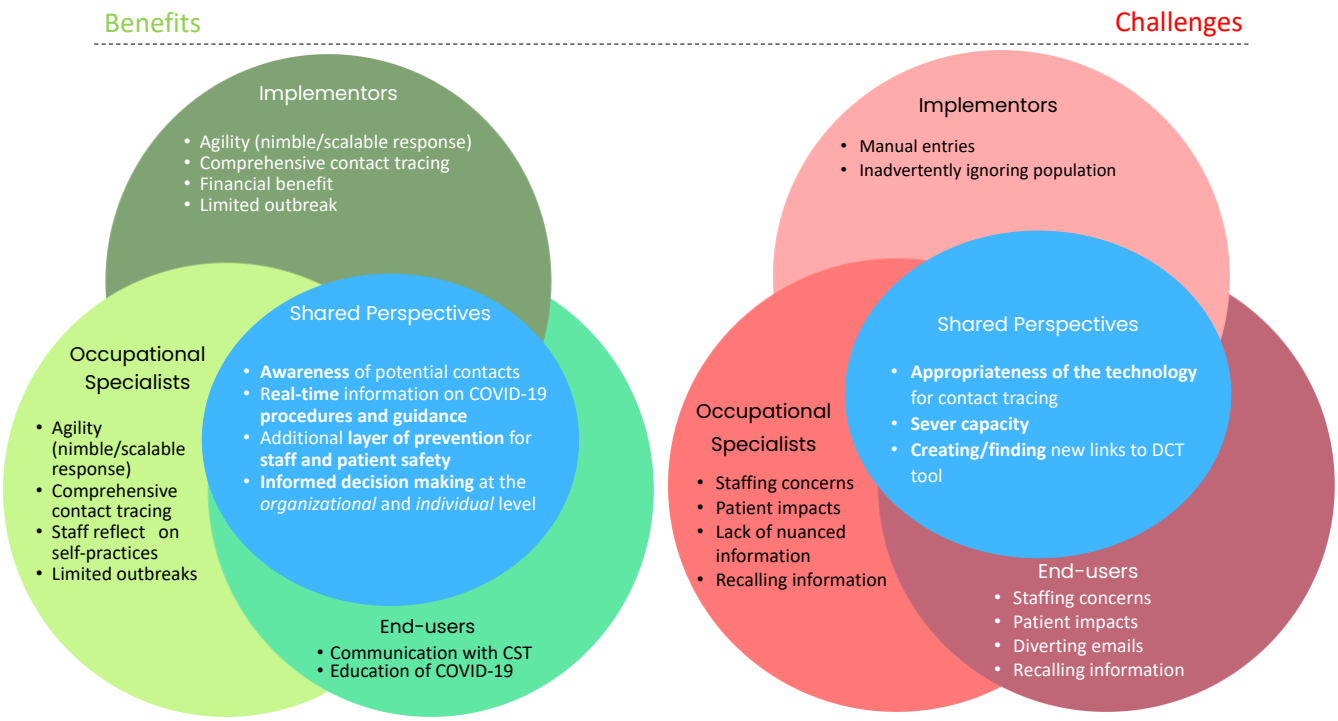

Figure 3. Stakeholders' Perceived Outcomes and Impacts of DCT

Adoption

Within "Adoption," I explored the factors influencing and hindering adoption at the setting-level. This included the strategies that were employed to increase the adoption of the DCT tool among staff (facilitators) and the factors that hindered its widespread adoption (barriers).

Facilitators to Staff Adoption

Safety-focused Culture

Overall, most participants among the stakeholder groups perceived that the DCT tool was *"well received"* and adopted by the *"large majority"* of staff. Implementors and occupational specialists described various safety-focused strategies that influenced the uptake of the DCT tool into routine practices. These included the provision of COVID-19 sick pay, communication of work standards, leadership engagement at varying levels, and regular updates on COVID-19 policies. Implementors and occupational specialists perceived that staff being initially paid for

time off related to COVID-19, as well as these absences being exempted from attendance programs, served as an incentive for staff to adopt the DCT tool.

> *"… During the pandemic, with the knowledge and understanding that if you were sick, there was pandemic pay. So, if you were off related to COVID, then you were paid. So, there was less hesitancy to report. And then since you were A) being paid and then B) the rule was that COVID-related absences wouldn't count towards the attendance program. So, if you were sick for, you know, several weeks, because you had contracted COVID, you wouldn't be penalized for those absences." P02, Implementor*

It was also acknowledged that the CST worked with the communications department to create newsletters and posts on the hospital's intranet, which also aimed to encourage staff to frequently check their emails to increase the uptake of the DCT tool. However, implementors emphasized that the overall messaging around the DCT tool was portrayed as the standard of work the organization was going to employ during the pandemic.

> *"… It was also communicated to staff, 'this is how CHEO is going to be doing contact tracing,' right? 'We're not going to phone; we just can't phone everyone anymore. So, this is what you can expect.'" P03, Implementor*

Personalized Guidance

Several implementors and occupational specialists identified that CST played a fundamental role in promoting the uptake of the DCT tool among staff. Many participants among stakeholder groups recognized the presence of the CST. Specifically, implementors perceived that the trusted nature of the nurses who were managing the DCT tool resulted in staff being more open to embracing the technology.

> *"They were a very trusted group of people. People were really counting on those nurses to keep them safe in the hospital." P12, Implementor*

Additionally, few implementors pointed out that staff were more inclined to adopt the DCT tool once they understood that it involved a *"direct touch"* of the CST, rather than being solely reliant on automated responses from a system.

> *"The staff that they had doing the COVID contact tracing, were really senior, well respected, sensible nurses, that people really trusted. I think once they appreciated that the people that were going to follow up with them, that were behind the scenes, there was really a real-life human being, and that was nurses that they knew and that they trusted." P07, Implementor*

This idea was additionally reinforced by several occupational specialists acknowledging their *"critical care"* background as an asset. Moreover, they acknowledged that the team was collectively committed and dedicated to upholding a high standard of contact tracing during the pandemic.

> *"We really tried to maintain a high standard. And we were all, as a team, willing to maintain that high standard. There was nothing ever was laissez-faire, or we could just do it. Or we'll just pop this out. It was always a high standard." P11, Occupational Specialist*

Consistent with this perspective, a few end-users also noted their appreciation for the nurses operating behind the DCT tool. These participants shared that the CST instilled confidence, specifically valuing the consistency of the information provided regarding how to manage their exposure to COVID-19.

> *"I was just happy that I had CHEO that I could reach out to. They had a small group, and they had the same information." P20, End-user*

Barriers to Staff Adoption

Misalignment with Frontline Practices

The most common barrier that persisted with the adoption of the DCT tool was that the *"… culture for frontline staff is not to routinely check emails" (P02 Implementor).* Implementors and occupational specialists indicated that a major challenge was getting staff to be *"aware and cognizant"* of their emails, particularly among those working shift work. It was noted that the CST could not "… *rely on [staff] checking their CHEO-based email" (P09, Occupational Specialist),* as some staff preferred not to receive or engage with communications from the hospital during their scheduled days off.

> *"Frontline staff are the people in the building, who use email the least frequently. Or they don't. Some of them are off, some of them don't get it on their phone. Especially maybe the (…) well, I wouldn't want to generalize. There's a portion of the population that just doesn't get emails on their phone. And also think, 'I'm not going to check work emails when I'm not working. I'm off for three days, I don't want to hear from CHEO, I don't want to think about CHEO, nothing.'" P03, Implementor*

Several implementors and occupational specialists also considered the hospital's multidisciplinary nature, especially in terms of how different healthcare professionals interact with their work emails. For instance, several participants perceived that staff with office-based jobs were more willing to adopt the DCT tool, as routinely checking emails is a standard

practice. However, it was noted that consistently checking work emails is not "… *necessarily part of [frontline HCWs'] jobs"* (P08, *Occupational Specialist*).

> *"You don't necessarily get the responses from doctors and nurses, but you'll get them from others. No pharmacy, no doctors, and most likely no nurses. Then if you have a social worker, all those (…) like everybody else. I feel like they respond more than everybody else." P08, Occupational Specialist*

> *"Because a lot of frontline staff don't operate as we do. We're sitting, we have an office job, where we're on our computers all the time, and we live in our email every single day. If you send me an email, I'm going to see it in a very timely way. For frontline staff, they're off and they might not check their email for three to four days." P03, Implementor*

This perspective was further supported by end-users who noted that despite their own *"rigorous"* email practices, this is not a shared custom among their colleagues. Subsequently, this may have led some staff to unintentionally overlook the DCT tool due to the volume of emails that individuals may receive.

> *"I have some colleagues, or just people that I know who, when I look at their little notification button on their email there's, like 246. So, I can imagine that in there, you could potentially have missed something." P01 End-user*

Sustaining Participation

Several of the participants expressed that initially, there was heightened concern regarding being exposed to COVID-19, which led to high rates of compliance. As the pandemic evolved, there was a large consensus among participants that staff members' perceived threat of being exposed to COVID-19 diminished over time. Many implementors and occupational specialists noted that this shift in perspective has also been influenced by the lack of prevention and control measures within the community.

> *"At the beginning. I feel like again, this is what I've heard from different people. They really wanted to be made aware, because then that could potentially affect other people that they would go see. Or some people do work in different locations, different hospitals, so they would up their PPE when they were working at their other job. And now they're just, 'since there's no restrictions in the community, then why am I still getting surveys?'" P08, Occupational Specialist*

Participants among the stakeholder groups also perceived the lower rates of continued adoption to be a result of frontline *"… staff [being] run off their feet" (P10, Occupational Specialist)* during the later stages of the pandemic. Not only did participants describe COVID-

19-related burnout, but some conveyed that staff fatigue was also intensified by the high volume of respiratory syncytial virus (RSV) infections experienced during the 2022 viral season. These participants perceived that this led frontline staff to view the DCT tool as an *"additional task"* to complete amidst their already heightened demands.

> *"So, they're exhausted, they're working overtime. And then there's this, it was just a lot. And plus, the sick kids and everything was just so much. So, I think that would be the biggest barrier for [staff]." P19, Occupational Specialist*

> *"I don't want to say that the survey is not work but doing frontline work. But just at the end of the day, you're done. You are just done. You don't want to anymore. So, why take extra time again to fill out the survey?" P08, Occupational Specialist*

Implementors and occupational specialists also recognized that certain clinical areas within the hospital, such as the emergency department, experienced higher levels of contact tracing fatigue. Participants perceived that once prevention measures improved and more knowledge about the virus became available, staff were frustrated with repeatedly completing the DCT tool when their answers remained the same. As a result, implementors and occupational specialists perceived that the *"redundancy"* of the DCT tool also led to higher rates of noncompliance.

> *"So, I know, emerg was constantly getting the tool because they're constantly exposed. Because obviously, they have more (…) it's less of a controlled area. So, they're constantly, the volume of people with kids that they're seeing is so much higher than other units, right? So, they were constantly getting blasted with the digital tool. So, they were over it. They were not filling it out by the end, they were not filling it out, or deleting it. They were just filling it out, just to fill it out." P19, Occupational Specialist*

A few implementors and occupational specialists recognized that staff may have engagement fatigue, as the DCT tool was distributed to staff with a "*wide net"* approach. As a result of staff receiving the DCT tool on several occasions, sometimes with limited relevance to being exposed to the positive case, participants perceived that the tool became *"white noise"* to staff over time. An occupational specialist also noted that if the DCT tool was tailored to be delivered only to those at the highest risk of COVID-19 exposure, this approach would have likely resulted in increased levels of staff adoption.

> *"If you have someone who gets one survey, and that's it throughout the whole pandemic, I feel like you might have a higher chance of response. But if you have one staff, who has a patient who's COVID-positive once or twice a month. Obviously, they're going to end*

up potentially having that survey. And why would they want to, let's say monthly, fill it out again?" P08, Occupational Specialist

While implementors and occupational specialists regarded staff fatigue with completing the DCT tool, no end-users in this study cited this as their reason for noncompliance. However, a few end-users highlighted that staff are likely *"surveyed out."* It is important to note that these participants mentioned that this was more relevant to daily entrance screening and organizational surveys rather than the DCT tool.

"In contact tracing, that was fine. But kind of the volume or the constant need for the screening questionnaire was a lot. I guess, the frequency of needing to fill it out would be a barrier." P13 End-user

Last, many implementors and occupational specialists also shared the belief that the challenges experienced with the DCT tool were not indicative of the DCT tool implementation being unsuccessful. Instead, they recognized that even with a traditional contact tracing approach, staff likely would have encountered similar issues with fatigue.

"*I think they would have been just as fatigued with the phone call; it wasn't the survey itself that was the problem. It was the number of times that they had to fill it out, that was the problem." P03, Implementor*

Adoption Summary

Participants among stakeholder groups discussed the various strategies employed to increase the adoption of the DCT tool among staff. Implementors and occupational specialists both emphasized that offering financial payment to staff who contracted COVID-19, communicating the standard COVID-19 work practices contributed to the overall uptake of the DCT tool. The participants also expressed a shared appreciation for the nursing team being the DCT, suggesting that their role behind the scenes made staff more open to using the DCT tool. Consistent with this, occupational specialists reflected on their collective commitment to maintaining a high standard of staff safety during the COVID-19 pandemic.

Regarding barriers, participants across the stakeholders agreed that the DCT tool did not align well with the standard practices of frontline HCWs, including their limited use of email and rotating shift schedules. This was particularly noted to be the case in certain clinical areas and among the frontline medical professions (e.g., nurses and physicians). Implementors and occupational specialists also shared that staff's evolving perspectives on COVID-19 and the

perceived threat of the virus impacted the continued adoption of the DCT tool throughout the pandemic. While some end-users expressed that the ongoing requirement to complete various organizational surveys contributed to survey fatigue, a few occupational specialists felt that the broad delivery of the DCT tool led to decreased compliance among staff. Importantly, it was noted that the contact tracing fatigue experienced by staff was a result of the DCT tool. Rather, participants felt that similar challenges related to compliance and fatigue would have been experienced with traditional contact tracing approaches as well. Table 6 provides a summary of the themes discussed under the 'Adoption' section, grouped by participants shared and unique perspectives.

Table 6. Overview of Adoption Themes

Theme	Shared Perspectives[2]	Unique Perspectives
	Facilitators	
Safety-Focused Culture	• Pandemic pay • COVID-19 related absences exempted from attendance programs • Communication of work standards	
Personalized Guidance	• Trusted- and reliable group of nurses • DCT tool involved a human touch point • Reliability of information provided from the CST • Collective commitment and drive for high standard	• *Occupational Specialists:* Collective commitment and drive for high standard
	Barriers	
Misalignment with Frontline Practices	• HCWs do not regularly check and utilize their employee emails • Rotating schedules	-
Ensuring Participation	• Declining response rate: evolving perspectives on COVID-19 and perceived threat of the virus • COVID-19 fatigue and burnout among HCWs • Contact tracing fatigue present in different clinical areas	• *Occupational Specialists:* Large distribution of the DCT tool impacted continued adoption • *End-Users:* Mandatory requirements of completing multiple surveys

[2] Two stakeholder groups or more shared similar perspectives.

Implementation

Within the "Implementation" dimension, I aimed to explore the key factors that influenced the implementation of the DCT tool. Additionally, I focused on exploring the process of implementation, namely the procedures required, and challenges experienced.

Factors Influencing Implementation

Maintaining Compliance

Implementors and occupational specialists were asked to discuss the factors that influenced the implementation of the DCT tool. First, a few implementors and occupational specialists acknowledged that the practice of contact tracing and disease surveillance within high-risk environments, including hospitals, is mandated by external governing bodies. One participant stated that contact tracing *"... is a practice that people would have done back when SARS was around, that public health does, that all hospitals would be doing internally" (P05, Occupational Specialist).* However, this also included the emerging set of policies set forth by Ontario Public Health, the MOHLTC, and the Ministry of Labor to mitigate the spread of COVID-19. One implementor stated that the hospital was regularly receiving *"... dictums from the Ministry of Health saying, 'thou shalt screen all patients before they come in, screen all staff before they come in, report all exposures, report all positive cases'" (P12, Implementor).*

However, an occupational specialist considered that the implementation of the DCT tool was solely a *"follow-suit"* action. Moreover, they expressed the belief that the hospital would not have emphasized contact tracing if other organizations, namely public health, had not initiated and emphasized such practices at the onset of the pandemic.

> *"It was just something that we were doing because we were following. (...). Because in the beginning, public health was contact tracing, they were doing all that. We sort of had to just follow suit being a high-risk setting, so. (...) I think if public health didn't do it, I don't know if we would have started to do it. We sort of follow what they do, they come out with their guidance, and we just follow what the guidance says." P10, Occupational Specialist*

Maximizing Efficacy

Many of the implementors and occupational specialists also noted the time-intensive and resource-exhaustive limitations of traditional approaches to contact tracing. Consequently, several implementors cited that there was a need for a more systematic way of conducting

contact tracing, which influenced the decision to leverage technology. Many implementors and occupational specialists perceived the DCT tool as a means to streamline and standardize processes and in an effort *"... to try and have a really timely contact trace" (P03, Implementor).* This concept was further supported by several implementors and occupational specialists:

> *"One of the big factors was if we had to send (...). Let's say, one positive staff, but that positive staff reported that they had worked with 10 staff. Well, if we did it manually, it takes half an hour to talk to person number one. So, by the time we get to person number 10, it's now we've lost some time there." P03, Implementor*

> *"I know that there was a lot of pressure on the system. That would have resulted in huge delays, and in contact tracing that would have rendered it quite meaningless if there hadn't been a way to sort of speed it up. ... I would [say] that from a leveraging technology standpoint, the ability to do it with less people, and quickly, and to get meaningful data that was standardized, to get all that back in real-time. I think would have weighed heavily on the decision to go ahead and implement it." P07, Implementor*

Participants also expressed that the DCT tool aimed to optimize the workforce during the COVID-19 pandemic. Implementors perceived that the substantial volume and the extensive nature of the contact tracing required for COVID-19 were the driving factors behind the decision to implement the DCT approach. Furthermore, implementors highlighted that the DCT tool reduced the dependency on resources at a time when *"... resources were scarce and continued to be scarce" (P02, Implementor).*

> *"... It was easy to recognize that there [was] literally no way we [could] keep up by doing it manually, one person at a time. …. That necessity, being the mother of invention kind of thing. Because there was actually no way we could keep up that, we were forced to come up with a better solution." P03, Implementor*

Implementors also emphasized the importance of accurate COVID-19 data retrieval for both internal and external reporting purposes on staff transmission and exposures. As such, the DCT tool was implemented to have an improved documentation system. From a due diligence and liability perspective, implementors also perceived that having surveillance data in a secure and well-organized database was a key consideration when implementing the DCT tool.

> *"And [to] make sure that the appropriate notifications are given to the appropriate bodies, both internally and externally, if there was any potential transmission. For example, Ministry of Labor, or if it was a worker to worker, or was a patient to worker if it was working related." P02, Implementor*

> *"I think it was because of the accuracy and the consistency. We were going to be asking the same questions. We would have it as documentation, to be able to go back and look at. And in future, if need be, any research around who would have the information. Because at the time that we implemented this, no one ever anticipated that it was going to go on like it did. But it was just a matter of being able to track that information, and really just have (…) from a due-diligence and accountability perspective of having the information in a secure in a well-organized fashion." P04, Implementor*

Although participants acknowledged the limitations of the DCT approach, few implementors and occupational specialists noted that it was the most viable for managing a labor-intensive process at the onset of the pandemic.

> *"I don't think it was a foolproof method. But I mean, it was something that they had to do. Because you can't be calling people 100 people every day saying that you could be a high-risk exposure. I think it was the only method that they came up with that was doable at that time." P10, Occupational Specialist*

Fostering Trust and Confidence

Implementors and occupational specialists also frequently cited the importance of building trust and confidence among staff during the COVID-19 pandemic. These participants perceived that creating an environment where staff could feel safe coming to work, despite the presence of being in a setting that was high risk for COVID-19 transmission, played a pivotal role in the implementation of the DCT tool.

> *"The number one internal thing. Well, internal and external, people were scared, right? People were really, really scared at the beginning of COVID. We didn't really know what this thing was, we didn't know how it was transmitted, and we didn't know how sick people were going to get. People were scared to come to work. It was really, really important to build trust among our staff, that we were doing all we could to protect them. So, that they could feel safe coming to work. That was one of the primary sorts of internal reasons for doing this, is we knew sick people would be coming into the hospital." P12, Implementor*

Transparency was also highlighted as a key factor influencing the implementation of the DCT tool. With the onset of the pandemic and the accompanying fear caused by the uncertainty surrounding the novel virus, implementors noted that there was a need to establish transparency among the staff. Specifically, the hospital was taking measures to ensure that staff would be informed if there were COVID-19 outbreaks or exposures within the workplace.

> *"It was evident to staff that there is transparency, 'we are being told when we have been in contact.' So, it was building that trust in the system." P02, Implementor*

> *"That was one of the primary sorts of internal reasons for doing this, is we knew sick people would be coming into the hospital. We knew people would likely be exposed as PPE as your last line of defense, not your first. Having a way of letting people know they've been exposed, tracking those exposures, and making sure they don't inadvertently expose others was incredibly important." P12, Implementor*

By implementing a process to inform staff about their COVID-19 exposures, several implementors and occupational specialists suggested that staff should have felt reassured knowing that their workplace was actively ensuring their well-being. One occupational specialist expressed that even if the DCT tool did not result in a specific outcome, its presence provided staff with a source of comfort at the onset of the pandemic.

> *"Because it gives people some comfort, that we were doing something, right? Even though it may not have come to anything, it gives people comfort. That they knew that maybe they were high-risk exposure." P10, Occupational Specialist*

Implementation Dynamics and Procedures

Innovative Leadership

Many implementors and occupational specialists recognized the immense contributions of the leadership team within the process of implementing the DCT tool. They noted that implementors also explained that a leadership team was established with a special focus on COVID-19-related matters shortly after the onset of the pandemic. Within this team, the implementation of the DCT tool was proposed and approved. Participants noted that particular leaders took the lead on this initiative very early on in the COVID-19 pandemic. Several implementors and occupational specialists valued these leaders, for their efforts in partnering with the necessary partners required for the successful implementation of the DCT tool.

> *"We had an Incident Management Response Team. IMT it was called. That was set up as part of the response to COVID. Decisions were taken there very quickly, so normal operational decision-making was kind of suspended. Everything went through IMT. This was very clearly the responsibility of the Safety team. So, [(Name)] really took the lead on it, she had a very clear vision of what she wanted. She partnered with the Research Institute because they were the ones who own REDCap, we don't actually have a hospital instance of REDCap." P12, Implementor*

Several implementors and occupational specialists shared the view that the leaders involved in the DCT tool were early advocates and champions of technology. One implementor mentioned that the implementation of the DCT tool was not an organization-driven decision;

rather, it was championed by innovative leaders who wanted to develop a tool that *"... could serve the hospital" (P12, Implementor).* Furthermore, many implementors and occupational specialists also highlighted that the involved leaders recognized the potential value of utilizing the REDCap platform, and their innovative approach was instrumental in guiding the implementation of the DCT tool.

> *"I would say at the time, the Director was very familiar with the capabilities of REDCap and was an early advocate for the adoption of the REDCap tool as a means to screen staff but then as a means to follow up with staff who may have self-identified as positive and then had consequently worked with other people." P02, Implementor*

> *"I do not think a lot of us necessarily realized REDCap. I think she was, in a positive way, a good influence on showing us what it could get to." P06, Implementor*

Several implementors and occupational specialists also noted that there were limited existing processes to follow in DCT practices, indicating that the tool was *"novel"* at the time of its implementation. One participant stated that the CHEO did not *"... have another center that [they] could learn from" (P09 Occupational Specialist),* which further highlights the leadership's innovative efforts.

> *"I think the most notable thing about it was the integrated nature of the tool that [(Name)] wanted to create. Most other organizations, they'd have one survey for the entrance screen and one survey for high-risk exposure and one survey for tracking stuff that maybe tested positive, and they were completely independent surveys. [(Name)] was very passionate about essentially making it a staff help tool. So, that we could track if someone was exposed, we could follow up with them, and see if they got it. If they got it, how did they do? It wasn't just a one-off question. It was actually an integrated system that helped us understand the effect of COVID on our staff." P12, Implementor*

Implementors noted that the existing use of REDCap for other processes within the hospital played a crucial role in influencing the decision to implement a similar process for contact tracing. In addition, implementors expressed that the leadership team involved considered various platforms before the implementation of REDCap. However, the REDCap platform was selected as it best aligned with criteria including financial considerations, security protocols, and integration with existing COVID-19 procedures. For instance, in cases where staff reported symptoms of COVID-19 or a positive test through the entrance screening REDCap survey, the CST was able to leverage this information to complete case investigations.

> *"I think the best route for us to do it was through the REDCap system because it could piggyback on the entrance screen. If someone had completed the entrance screen, and*

> *they noted something on there. They would report their test backs through there. Then, the COVID RNs would be able to find out that person had tested positive. They could further contact trace them to find out 'Oh, they were at work two days ago,' or x, y, and z." P06, Implementor*

Implementors and occupational specialists also expressed that various leadership teams within the hospital, including top-level leadership, actively bought into the concept of the DCT tool based on its safety impacts. Implementors and occupational specialists also noted that staff were frequently reminded about the DCT tool during *"daily briefings"* and *"nursing huddles"* led by clinical leaders, such as frontline managers and educators. It was perceived that having the DCT tool promoted by top-level leadership had a cascading impact, leading to its successful implementation.

> *"I think there was an executive level by in. Because we could demonstrate, 'Look, we're getting this. We're seeing this, this is helping us. We have very, very low transmission rates.' Because of what we were doing." P04, Implementor*

> *"There was definitely buy-in from all levels of leadership. I think that if you can get your CEO and all the directors buying in, then it's just a trickling effect. Because then management, and then management passes the word to staff." P11, Occupational Specialist*

Aligned with this, an implementor perceived that the hospital's leadership team efficiently communicated that the DCT tool not only served to mitigate COVID-19 exposures but also as a mechanism to monitor the well-being of staff. Subsequently, this communication was perceived to impact the success of the DCT tool.

> *"The messages from leadership started to be a bit of a balance between taking care of yourself, keeping yourself safe, and that this was part of it. As well, as the patients, and patients and families. … 'We care about the patients and the families who we're here to serve. That's our priority as an organization, that's why we exist. But we care about we care about you.' I think that once that message got out, people began to see that the point of the contact tracing was to keep them safe." P07, Implementor*

Collaboration

Another key theme identified by the implementors and occupational specialists was the collaborative implementation process. Several participants indicated that multiple stakeholders were involved during this process to ensure that the DCT tool met an operating standard, including the members of the CST, managers, and directors. Implementors expressed that the

implementation of the DCT tool necessitated collective efforts, specifically for understanding the needs and defining what the tool was intended to capture.

> *"We looked at what our requirements were. We looked at the demographics which is the 'who, what, when, where, how, and why.' We kind of walked through who they were, who they reported to, and what we needed to know. We did try to figure out the types of questions we would want to use in the tool. Also, keeping in mind, whatever the requirements were with the case and contact management guidelines at the time." P04, Implementor*

Many implementors shared similar perspectives that actively involving the nurses in CST was essential during the DCT tool implementation. These participants recognized the value of involving such stakeholders to aid in developing a comprehensive set of contact tracing questions that could be delivered through the tool. Furthermore, few implementors noted that the CST remained consistently involved throughout the entire process of the DCT tool implementation and ongoing stages.

> *"… We would have gotten input from the nurses to say, 'What's the list of standard questions that you ask? What should we include?' Then we would have developed a bit of a proof of concept of the REDCap survey, and we would have shown it to the COVID nurses to say, 'Does this look reasonable? Is it ready to try?'" P03, Implementor*

Implementors and occupational specialists also acknowledged that the implementation of the DCT necessitated collaboration between various departments within the hospital. Several of these participants also noted the contribution made by the REDCap team, housed under the Research Institute, during the development, implementation, and ongoing maintenance of the DCT tool. One participant stated that *"… the REDCap team [was] very big in implementing the start of the contact tracing" (P11, Occupational Specialist)*. Furthermore, a few implementors and occupational specialists highlighted that the hospital's IPAC team was *"intertwined"* with the CST during the implementation and throughout ongoing changes to the DCT tool. Specifically, participants noted that the IPAC team actively participated in refining questions within the DCT tool through iterations.

> *"Initially, 'Okay, well, you're missing eye protection.' Okay, well, now it was this. A lot of those things came through infection control. … We would help to facilitate the language so that the tool could be written." P07, Implementor*

Implementation Challenges

Digital Disconnect

Most implementors acknowledged that the implementation of the DCT tool was a straightforward process, despite a few challenges being encountered during the implementation period. First, a few implementors also expressed that the urgency of the COVID-19 situation led to staff not being properly prepared for DCT tool implementation, as the CST *"... did not have [the] option to be doing a lot of advanced, or to be doing any advanced communication" (P03, Implementor)*. Likewise, some end-users mentioned that the DCT tool was "*... a bit of a surprise" (P01, End-user).* However, others expressed their excitement regarding the implementation, citing that it is *"... the new generation of having everything online" (P18, End-User).*

A few implementors expressed that some staff voiced concerns regarding the DCT approach being email triggered. Primarily, this was a result of staff anticipating that they would be notified immediately after their potential exposure through phone calls. Furthermore, one end-user expressed that the introduction of the DCT tool may have unintentionally "*... created a lot of anxiety for people" (P16, End-user),* as a result of being electronically notified regarding their potential exposure.

> *"I think there was initially, from what I remember being up on the wards, and people were nervous. I think people did think, 'Well, that's nonsense. They should have called me. They just should have called me and told me. I have been at home with my family. I could have made my family sick, and they send me an email, like come on.'" P07, Implementor*

Although the DCT tool aimed to increase staff's confidence in the hospital's safety efforts and to provide timely guidance, it was acknowledged that some staff *"... desire to have the phone call never totally went away" (P03, Implementor)*, which highlights that the implementation may not have achieved fidelity as intended. Furthermore, a few occupational specialists acknowledged the importance of *"human connection"* and *"reassurance"* in high-stress scenarios.

> *"Sometimes [we] think of good intentions of setting up electronic and sending these emails. [But] people can be stressed, and they won't read what you're sending. Or they're reading it, but they're not taking it in. So, sometimes it's having that human connection of calling them, and telling them that they're going to be okay." P15, Occupational Specialist*

Conversely, these perspectives were not unanimous among all implementors and occupational specialists. For instance, an occupational specialist highlighted that many staff were

in a state of *"panic,"* and the DCT tool enabled the CST to provide rapid guidance, which could "*… not have been done if it was a phone call" (P11, Occupational Specialist.* Furthermore, an implementor expressed that over time, staff became more positive about the DCT tool because of its impacts.

> *"I can only assume that they would feel happy that we had done that, to be honest with you. I think it did help a lot of individuals, having it be such a quick process and having it be so easy to collect the data, and having our COVID RNs reach out to people to let them know, 'in case you didn't know, you were a contact of a contact,' or whatnot. I think that their view on it has only become more positive because they've actually seen it working." P06, Implementor*

Although it was a minority perspective among end-users, one participant did mention a preference for the traditional contact tracing approach employed by Ottawa Public Health. They cited that the traditional phone-call approach facilitated longer conversations, particularly regarding education and reassurance after being identified as a high-risk COVID-19.

> *"I also really appreciated the Ottawa Public Health follow-up versus CHEO's occupational health follow-up. I had more follow up from Ottawa Public Health and lengthier conversations. They appeared to have more time to educate and walk you through and provide that extra level of comfort." P16, End-user*

Resource Management and Partnership

A key theme that also emerged was the challenges related to relying on external partners for technical support to successfully implement and operate the DCT tool. Implementors identified that they needed external assistance to set up and initiate the DCT tool. As the hospital did not have its own instance of the platform, there was a dependency on its partnered organization (e.g., Research Institute) and its administrators to provide the necessary technical expertise to support the implementation.

> *"Again, we're using a REDCap system, and in the very beginning, we had to heavily rely on the REDCap administrators, which were housed under the Research Institutes home. We had to rely on them to kind of help us with some of the building and teaching us how to work the system, which is now basically what I do. We had to kind of rely on external [resources] in a sense, to help us a little bit with getting that up and running." P06, Implementor*

A few implementors also identified challenges that arose during the implementation and ongoing stages of the DCT tool because of the complex back-end of the platform. Considering that the members of the CST came from a clinical background and had no formal training in

technology programming, participants expressed that challenges were faced by the CST in acquiring the required skills necessary to use the back end of the DCT tool. This was further supported by a few occupational specialists who described that the *"... tool was not super user friendly" (P21, Occupational Specialist)* from an operational or back-user standpoint. Participants also acknowledged that aspects of the DCT tool's platform, specifically the back-end requirements, were *"tedious"* and posed difficulties.

> *"... We had to learn some REDCap details. That might have been because we're not programmers. And then all of a sudden, you're like, 'Oh my, God. I feel like now I'm having to be a computer programmer.' Our own ineptitude, I guess, with that was one challenge." P03, Implementor*

A few implementors and occupational specialists also noted that the external partners supporting the DCT tool had regular responsibilities, which led to delays when addressing any modifications or updates to the tool. Although most participants stated that coordination generally occurred quickly, some participants expressed that there were instances of delays in updating the DCT tool. Consequently, this situation was perceived to have negative consequences, such as impacting staff pay and work status.

> *"But there were times where we could implement something that was pretty important. Like the travel, that was huge. People would go travelling, they'd have to get tested. And then that changed, we'd have to wait. So, that was big (...) we couldn't just go into change it quickly. We'd have to have a meeting or have REDCap involved so that they could change it and okay it, and all that stuff. So, that would be the only thing. Because then it would affect staffing, and it would affect staffing people's pay. And because they're isolated, when they really didn't have to isolate, little things like that." P19, Occupational Specialist*

Additionally, a few implementors and occupational specialists expressed the presence of interpersonal conflicts and tensions during the implementation period. Primarily, this was perceived to be a result of some questioning the feasibility of using the REDCap platform for DCT. Participants also expressed tensions regarding how *"... mature and holistic the system should be compared to how simple" (P12, Implementor).*

> *"REDCap was never intended, in a sense, to be used for contact tracing. It's just a research tool, not something for contact tracing, for screening, and whatnot. It wasn't originally intended to be that way. I think there was a little bit of apprehension in terms of, 'We're starting this chain, and can we continue on with it?'" P06, Implementor*

Despite these challenges, one participant expressed that the CST and the external partners demonstrated a strong commitment to the continued use of the DCT tool. Furthermore, participants emphasized that any challenges experienced were overcome by having a dynamic team oversee the DCT tool and utilizing a collaborative approach to facilitate any necessary changes.

> *"I think any barriers that we faced, it was a very dynamic team, and they were addressed quickly. I think that we were able to (…) if we couldn't come up with a solution quickly, [then we would bring] it to the managers, bring it to the directors, run it by [(Name)], and then bring it to REDCap. Then, it was fixed." P11, Occupational Specialist*

Implementation Summary

Implementors and occupation specialists discussed the influence of external governing bodies and their subsequent policies on COVID-19 as a factor driving the implementation of the DCT tool. However, implementors also recognized that the potential for transmission to occur within the clinical environment, alongside the need to build trust among the staff, were factors influencing implementation. Additionally, implementors noted that the DCT tool was a mechanism to increase transparency among staff by assuring them that protocols were in place to inform them of COVID-19 exposures. Implementors and occupational specialists also cited that, given the limitations of traditional approaches, there was a need for a more efficient contact tracing process. Despite many implementors and occupational specialists acknowledging that the DCT tool was not foolproof, it was considered the most viable option at the time to meet the surging demands of the pandemic.

Regarding the implementation process, implementors and occupational specialists credited the importance of the leadership team for the successful implementation of the DCT tool. It was also emphasized that various levels of leadership bought into the DCT approach and were committed to its successful implementation. Furthermore, implementors and occupational specialists highlight the value of collaborating with stakeholders – both internally and externally. In terms of implementation challenges, implementors found the implementation of the DCT tool to be a relatively straightforward process. However, few participants among the stakeholder groups acknowledged that there was an initial disconnect between staff and the DCT tool. End users expressed that some staff may have felt overwhelmed by the introduction of several new technologies and mandatory processes during the pandemic, leading to increased anxiety. A minority of end users expressed a preference for traditional contact tracing approaches over the

DCT tool, as it allowed them to have more detailed follow-up after being exposed to COVID-19. Finally, implementors and occupational specialists identified some challenges related to reliance on external partners for ongoing maintenance of the DCT tool.

Additionally, few implementors highlighted that tensions were present during the implementation period. This was primarily related to the choice of the platform for DCT and the required complexity of the system. Fig. 5 demonstrates an overview of the themes discussed under implementation, including the factors influencing the implementation of the DCT tool, the dynamics and procedures, and the challenges experienced.

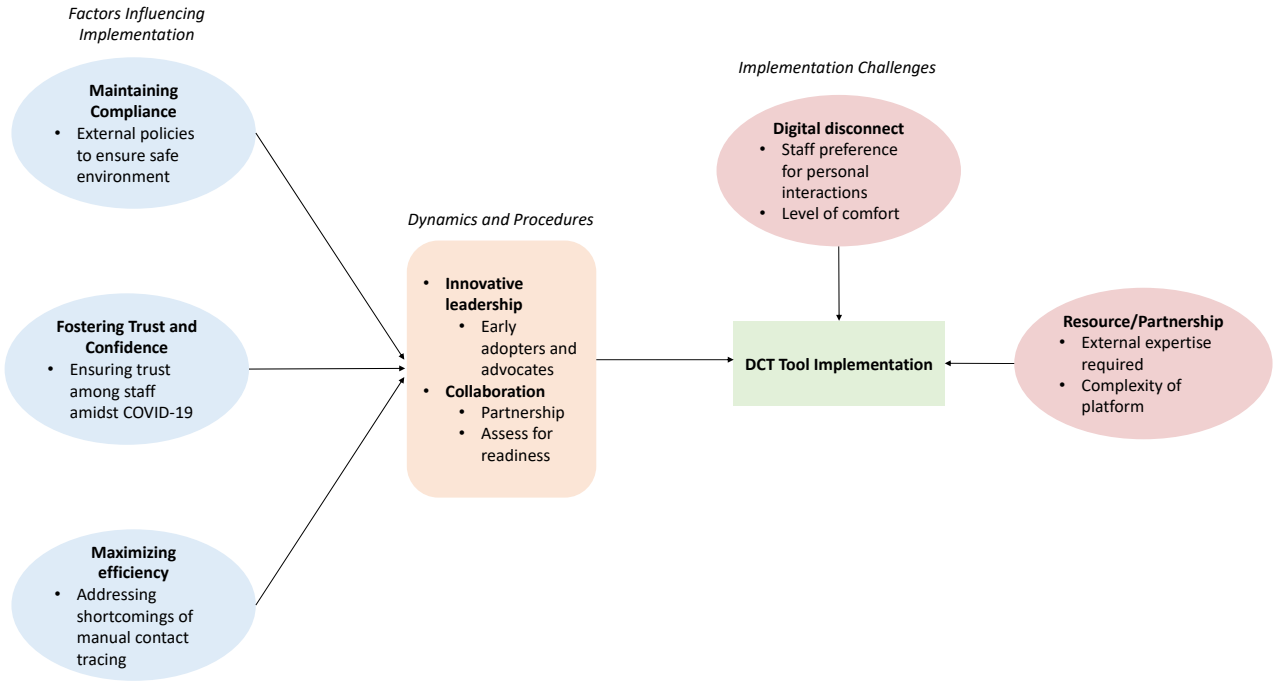

Figure 4. Overview of Digital Contact Tracing Implementation and Procedures

Maintenance

As the DCT tool was utilized for >6 months, the "Maintenance" dimension explored how the DCT tool was adapted for long-term use (Glasgow et al., 2019). This included investigating the various adjustments made to the DCT tool and the reasons for these changes. Expanding on this, I also explored participants' perspectives on the sustainability and feasibility of extending the application of DCT into different infectious disease contexts.

Adaptations and Modifications

Many implementors and occupational specialists recognized that the DCT tool required several adaptations to be made, with one participant stating that it was *"… huge work in progress" (P03, Implementor)*. To facilitate an ongoing process of improvement to the DCT tool, implementors and occupational specialists noted that feedback was obtained from various stakeholders. First, several implementors valued the active involvement of the CST in suggesting improvements and modifications aimed at not only enhancing their workflow processes but also the DCT tool's user-friendliness. By having consistent weekly meetings, the CST was able to provide input, suggest improvements, or address concerns related to the DCT tool.

> *"We would have weekly touch base meetings, so that we could talk about, not just this survey mind you, it was all REDCap things. But what can be changed to either make the workflow more efficient? In terms of at some point, we developed standard responses. Like drop-downs and standard responses that [staff] could select, as opposed to all free text. But [the CST] were involved all along, in order to really make sure that we were improving the tool as we went." P03, Implementor*

> *"It was a constant, every Wednesday touched to see, 'is this tool still accurate? Are there any updates that we need to make? Any tweaks that are going to make it more efficient for yourself and for the staff?'" P06, Implementor*

Additionally, many implementors and occupational specialists found that the feedback mechanism integrated into the DCT tool (e.g., comment box) facilitated driving improvements for end users. One occupational specialist expressed that the CST continuously worked to "*…make it easier for the staff that were using it" (P19, Occupational Specialist)*. Supporting this notion, many end-users also perceived that the DCT tool progressively became more efficient and simpler to use over time.

> *"… They definitely revamped it. They have fixed it up so many times. And they kept on making it better and quicker. Before they would ask so many, it would take me five minutes, literally to fill it out. But then they made it straight to the point, that it was quicker for people to do it. It would take less than a minute to fill it out." P18, End-user*

Furthermore, several implementors and occupational specialists noted that various adjustments were made to the delivery of the DCT tool throughout the COVID-19 pandemic. For example, changes were made to meet the specific demands of the emergency department, where there was a surplus of COVID-19-positive patients. Instead of the CST focusing on intensive

case investigations among a patient or staff testing positive in the emergency department, they transitioned to placing more responsibility on staff to be accountable for managing their exposures. This approach was regarded as a similar process taken for other infectious diseases, which entailed staff contacting the CST when they had concerns about their exposure or potential breaches among interactions with colleagues or staff.

> *"We kind of took on the same model that we would use for other infectious diseases. Say somebody on the unit that had meningitis, measles, or chickenpox, and someone was taking care of that person, and they may have thought they might have had a breach, they would report that. What we said is, 'If you feel that you may have worked with this person, and you feel that you may have had a breach, contact us.' Then, if they contacted us, then we would do the contact tracing. That was specifically in emergency, because every person that was coming in pretty much was COVID, and they were wearing all the universal precautions." P04, Implementor*

One end-user also perceived that the shift in the delivery of the DCT tool was a result of a change in understanding about the risk of COVID-19. At the beginning of COVID-19, staff wanted to have access to information regarding their level of COVID-19 risk. However, as the pandemic progressed and the number of positive cases surged, this participant perceived that it became evident that their exposure to COVID-19 would be a persistent concern.

> *"I think it just became so common, if there was a COVID-19 test positive. And after a while, we just assumed everybody was COVID-19 positive. And so, in the very early stages, it was all about getting information, [and] understanding that you might have been at risk. And then after time, it just became clear that you were always at risk." P01, End-user*

Similar processes were employed for the rest of the hospital during the influx of the Omicron variant. Instead of conducting large-scale contact tracing exercises, the CST relied on positive staff determining who they had been in close contact with without the appropriate PPE in place. Subsequently, the DCT tool was delivered to those with a higher risk of exposure. While not reported by all participants, it was observed by an occupational specialist that this approach was less labor intensive and less time exhaustive, yet it did not impact the rate of transmission in the hospital.

> *"When we got slammed with Omicron, it was, we couldn't do that anymore. Because we're getting 30, 40, 45 new cases a day. So, we couldn't just keep contact tracing that way. So, we ended up relying on the positive case itself, to let us know who they had contact with. And we only send it to those people. And then that was way better. And in*

the end, we found out its less work, its less people, and that it didn't increase our high-risk contacts or increase transmission." P19, Occupational Specialist

Sustainability for COVID-19

There was a range of opinions among participants about whether the use of the DCT tool should be continued during the COVID-19 pandemic. At large, most participants expressed a strong desire to sustain the DCT tool, and many applauded its positive impacts. However, a minority of participants perceived that the DCT tool was no longer valuable among staff or the hospital and advocated for its discontinuation.

A few implementors also perceived the DCT tool to be a *"brilliant"* response to the COVID-19 pandemic, justifying its viability for long-term use by the outcomes it generated. One end-user also expressed their desire for the tool to continue to be utilized by stating *"... I hope they don't replace it and I hope they don't phase it out either." (P17 End-user).*

> *"I don't see why it wouldn't be sustainable. It does work quite well, it's really efficient in terms of our ability to reach multiple people very quickly, receive the reports, or receive the responses, and whatnot." P03, Implementor*

However, several participants among stakeholder groups mostly perceived that with further refinements, the DCT tool could be maintained successfully (outlined in the section below titled "Areas of Improvement"). A few implementors and occupational specialists commented that the sustainability of the DCT tool would be influenced by whether the hospital could continue to efficiently manage the capacity of the platform currently being utilized.

> *"Is REDCap the answer to it? I don't know. I don't know if REDCap is kind of busting at the seams and can't take much more, I'm not really sure." P11, Occupational Specialist*

In contrast, a minority viewpoint was that the DCT tool was not sustainable for COVID-19, as the perceived risk of COVID-19 continues to diminish.

> *"It's tricky, I don't know what they're going to do going forward because we can't keep contact tracing for COVID, because no one cares anymore. Because it's everywhere, it's in the community. People aren't dying like they used to be, it's not (...) I just don't think it's a big enough thing anymore that we need it for this." P10, Occupational Specialist*

Transferability Beyond COVID-19

Many of the participants across stakeholder groups expressed that the DCT tool presents the *"... opportunity to expand [the] application beyond COVID-19" (P09, Occupational*

Specialist). Several stakeholders expressed the idea that as *"... COVID is only one of many exposures [staff] could have" (P05, Occupational Specialist),* having similar mechanisms in place for infectious disease management would offer additional assurance in protecting staff and patient safety. Furthermore, another end-user noted the potential for the DCT tool to be *"... useful on a broader scale" (P14, End-user)* by being integrated into standard practices for infectious disease control.

> *"I wonder, not just for COVID, but other illnesses and for contact tracing. I think chickenpox. I think of the measles, right? I just feel like this would be a great tool for all other illnesses." P20, End-user*

Given the DCT tool's established foundation gained through the COVID-19 pandemic, several implementors and occupational specialists conveyed confidence that with proper expertise, the tool could be adapted to *"... whatever comes [their] way in terms of pandemic, epidemic, or infectious concern" (P02, Implementor).*

> *"But it would be easy to take the current tool and adapt it for all viruses or infections. It could be used for Ebola, it could be used for TB, could be used for MERS, any illness. And hopefully not the bird flu. But for any epidemic or infectious disease that may have public health concerns, the tool can easily be adapted to fit whatever is going on. So, even though it may go away for COVID, I imagine it would be used in other scenarios." P04, Implementor*

> *"I do think that tool would have to be tailored to whatever your contact tracing. But I think this method of contact tracing could be sustainable for sure. As long as you have the right contact experts, who are able to tailor it accordingly." P05, Occupational Specialist*

However, one end-user pointed out the importance of considering whether the use of technology facilitates actions (or inactions) at the organization or individual level. This participant emphasized that without these essential outcomes, a digital approach to contact tracing would be rendered meaningless.

> *"So, if you were to apply a similar tool to say, an outbreak of Ebola or something else, for a defined period of time. The answer would be, yeah. (...) As long as there's a way that tool helps either the organization or the individual understand, how that tool translates into an activity or an action. Or maybe even an inaction, right? Then, yes. But you can't keep going on with a tool if it's not helpful anymore." P01, End-User*

It also noted that the continuation of the DCT tool beyond the context of COVID-19 would be dependent on the presence of organizational alignment, such as having staff, leadership, and financial buy-in.

> *"It would need to be a project, it would need to have an infusion of support, enthusiasm, and probably money to be able to set up REDCap contact tracing for all of the things that they have to contact trace, but I could see that. Again, I think it'd be very leadership dependent. But I can see the value." P07, Implementor*

Another end-user suggested that the translation of DCTs into routine infectious disease monitoring practices would be dependent on not only appropriate financial resources but also scientific knowledge or evidence regarding the approach.

> *"I guess it's just the money thing. If there's if there's enough money to maintain the program. If there's enough impact from current studies, current research, or current public health initiatives. Then, I don't think there's any reason why it would be difficult to maintain. I think it's sustainable for sure." P13, End-user*

Maintenance Summary

The DCT tool, as described by many implementors, exhibited an iterative nature throughout its ongoing maintenance. First, implementors expressed the value in gaining input from the CST, as they were the ones who utilized the DCT tool most frequently. To enable this, outstanding meetings were scheduled to discuss how the tool could be improved. Additionally, implementors and occupational specialists described how the comment boxes were utilized to facilitate improvements. End users also noted that over time, the various refinements made to the DCT tool made it more efficient and user-friendly.

Implementors and occupational specialists also highlighted the various adaptations made to the DCT tool to meet the evolving needs of staff during the pandemic, such as adjusting the delivery. A few occupations noted the success of alternating the delivery of the DCT tool to only those at the highest risk of COVID-19 exposure. Specifically, they perceived that this led to a less labor-intensive and time-consuming process that did not impact rates of nosocomial COVID-19 transmission.

Participants among the stakeholder groups had differing opinions on whether the DCT tool should be continued for COVID-19. Most patients expressed a strong desire to sustain the contact tracing effort, citing several of its positive impacts on patient and staff safety. However, a minority of participants felt it no longer held value and advocated for its discontinuation. Implementors and occupational specialists believed that its long-term viability would depend on

the ability to maintain the capacity of the platform, while end users suggested that it should be evidence-based. Notably, there was an overall agreement among stakeholders that the DCT approach could be adapted for various infectious disease scenarios, given its established foundation. However, one participant stressed the importance of such innovations translating into direct actions for the end user, either at the individual or organizational level. However, implementors highlighted the role of financial buy-in and leadership support for the sustained integration of DCT into standard practice.

Optimizing Digital Contact Tracing Practices: Areas of Improvement

Enhanced Usability and Access

Several participants across stakeholder groups identified several factors to improve the DCT tool. First, participants expressed that the overall structure of the survey appears to be *"convoluted"* and suggested that refining the questions to align with the current COVID-19 situation increases its usability for staff. End-users further highlighted the need for contact tracing questions to be consistently reviewed to ensure that they are "*pertinent"* and *"simple."* For instance, one participant cited that "… *asking the right questions, with the right length of time, is important" (P16, End-user),* which further highlights the need for DCT tools to be precise.

> *"I feel like it just could just be a lot simpler. … It doesn't need to be so confusing and difficult if that makes sense. It doesn't need to be so, at this point. Maybe in the beginning, it did, but at this point, it doesn't need to be." P10, Occupational Specialist*

Stakeholders also suggested making improvements to ensure that the DCT tool was more intuitive to use. Namely, this concerned the functionality of the technology. End-users suggested that using a select response format, such as drop-down menus, would simplify the process for users.

> *"And then, they also asked if you were ever positive, 'What's your manager's email?' Maybe a drop-down would have been helpful, and then just pick the name. I also didn't find it very pretty. It was very, I didn't like the (...). They could have done a little, they could have found another software to make it a little bit more, user friendly or a little bit prettier." P20, End-User*

Implementors and occupational specialists also noted that standardized responses could reduce manual requirements for back-users and enhance reporting by having more consistent information collected.

> *"I would remove all the free text boxes where possible and put in the drop-down menus, just because I think it's easier for data analysis at the end." P06, Implementor*

A common perspective shared by many participants across stakeholder groups was that accessibility to the DCT tool could be improved. By improving and simplifying access, participants perceived that staff could more conveniently engage with the DCT tool. To address this, participants emphasized that one way of improving access would be the development of a *"need-to-know"* page or a clear icon specific to contact tracing integrated into the hospital's intranet page.

> *"The ease, like I had said, an easier access button. Maybe on CHEO Net, that's a quick button. If it's not already done. Or I think, well, sometimes CHEO Net, you toggle some stuff and then gives you, it brings you into a whirl. So, just an icon or something that's really clear." P20, End-user*

> *"I think really the awareness and the accessibility piece too. Making sure that, because it's a link that you actually have to click on. … Just making sure it's accessible to people, so that they're not constantly, emailing and trying to hunt something down that they need to find." P06, Implementor*

Many implementors and occupational specialists also questioned whether alternative strategies could be used to distribute the DCT tool, such as linking the tool with SMS messages or always having it readily available to staff.

> *"I think (…) you know, could it be a notification, a push SMS text message to your phone to say, 'Oh, go check your email because you've been identified as a high-risk contact and we're doing our contact tracing. Please go check your email to complete the form.'" P02, Implementor*

> *"I do think it should be available that people can just look up and say, 'Okay, would I be considered a high-risk exposure?'" P10, Occupational Specialist*

Prioritizing Education and Training

Participants across stakeholder groups highlighted the importance of proper education and training for end-users and back-users (e.g., CST), respectively. For end-users, several participants noted the importance of providing staff with sufficient education on contact tracing practices, the DCT tools' purpose in aiding the process of contact tracing, and the safety impacts

it brings at the individual and organizational levels. Participants suggested that providing staff with additional communications, such as video explanations, tip sheets, detailed "how-to" processes, or answers to frequently asked questions (FAQs), could support this effort.

> *"As far as communication, about whether it's a quick little two-minute tutorial, or a video, or a quick FAQ around why this is important. What we do, and why it helps, let people appreciate the utility of it. That it's worth using because look what it provides in the end." P04, Implementor*

However, it was noted by an occupational specialist that the education provided to staff should not solely rely on email or technology-based communications. They emphasized the importance of tailoring the delivery of education to be aligned with the standard practices among frontline workers, such as nursing huddles.

> *"But again, communication is always done pretty much through emails and if you're a frontline worker, you're not checking your emails. You just don't have the time. I think more of like in-person communication, doing like nursing huddles or in your nursing meetings in the morning." P10, Occupational Specialist*

In alignment with this belief, an end-user also pointed out that having "*proper information and training"* during the implementation phase would be beneficial. It was perceived that by offering training sessions or having readily available technology support on the units, staff would have been better equipped to properly utilize the DCT.

> *"So, having, for example, a team of people that would go to a unit that would help people download it onto their iPhone or to provide shortcuts on your computer on where to find it. ... Setting up a training session for people who don't navigate their cell phones with ease, right? So, to have somebody techy, to sit beside them to go through that." P16, End-user*

Implementors and occupational specialists also acknowledged that a more efficient workflow may have been achieved if the CST had received additional training on how to utilize the DCT tool and its platform to its full potential.

> *"I think having some expertise amongst, could it be before they rolled it out, could they have spent that with the COVID nurses? Could those COVID nurses have done a three-hour (...) they're all brilliant, brilliant, really strong nurses. Could they have done a three-hour REDCap workshop? And taught them how to deal with it, to be able to make sure that the changes could happen seamlessly and be really responsive to changes as the guidance changes." P07, Implementor*

Few occupational specialists supported this by expressing that the additional steps taken in the contact tracing process, specifically related to their manual efforts, may have been an outcome of not having the necessary knowledge to utilize REDCap to its maximum capacity.

> *"… I do think a lot of it was us just not knowing how to use all of REDCap properly to capture it, to analyze the data properly." P21, Occupational Specialist*

In line with this, implementors and occupational specialists also perceived that enhancing internal expertise for operating the DCT tool was a crucial area for improvement. By having additional internal expertise, participants perceived that their reliance on external resources could be reduced.

> *"So, it would have been nice to have, a bigger, a larger number of people that could support this. Even now, there's such complex coding, that really, there's only one person with the expertise." P02, Implementor*

To address some of these concerns, a few implementors and occupational specialists suggested that shifting toward an in-house managed platform may be considered in future developments. They emphasized the importance of exploring a platform that could improve usability for both end-users and back-users while also meeting organizational needs.

> *"MS [Microsoft] forms (…) we think might be a lot more intuitive, in terms of our ability to develop new surveys. It is got a lot of (…). And maintain them if we have to make changes. As opposed to this saga of coding and whatnot. I also think that it might have lots of the same functionality, and potentially even better in terms of our ability to pull reports and stuff. So, I think we have to learn about it." P03, Implementor*

Integration and Expansion

Several implementors and occupational specialists also identified an opportunity to leverage more advanced technology to automate the *"tedious"* tasks that were manually required by the CST. For instance, one occupational specialist expressed the belief that the hospital is not using technology *"… up to the standard that [they] could be" (P10, Occupational Specialist).*

Furthermore, a few implementors and occupational specialists also expressed that if existing clinical systems (e.g., EMR system) and information systems (e.g., human resources systems) were better integrated, it would take less time and manual requirements to capture patient-to-staff or staff-to-staff interactions. Although *"… everyone post-COVID [is] working on how to integrate [these] systems" (P12, Implementor),* it was also recognized that health technology is still relatively immature, and such efforts demand both time and financial

resources. Last, it was also emphasized that future developments of DCTs will communicate and report staff or patient data in a *"privacy-appropriate way."*

> *"We had no real way of integrating sort of our lists of staff and who was working on that shift and things like that with the system. It was a very manual process. If a patient came into the ED at this time, people would have to go into the schedule, figure out who was on that day, and then send the survey to those people. Versus, in an ideal world, and if this was in banking or somewhere else, chances are, you just be able to say, 'Oh, there was an exposure' push a button, and the software would do it all for you. Figuring out who was scheduled that day, maybe who interacted with that patient, and then target the survey exactly to those people. But our HR systems, our security systems, and our clinical systems are not linked up enough to allow for that. We're working on it, we'll get there, but not yet." P12, Implementor*

A few end-users also suggested that expanding the DCT tool to be delivered to patients and their families would be beneficial if they had possible COVID-19 exposure at the hospital. One noted that the DCT tool would provide them with the necessary information to *"... be aware and test" (P13, End-user),* in addition to being provided with the required protocols to follow. Moreover, another end-user suggested that the DCT tool could be further expanded to improve the *"... general scheme of situational awareness" (P14, End-user).* Specifically, by reporting on aspects such as air exchange levels, this end-user perceived that the DCT tool could enhance internal transparency among staff regarding the hospital's proactive efforts to prevent COVID-19 transmission.

> *"I know a lot of issues have come along with regards to, how's air exchange? ... I don't know if that's something that can be integrated within the tool as well. Or [to] have an understanding of, is the organization doing more than simply doing more preventative things? Rather, than retroactively in terms of contact tracing? And if that has a mitigating factor in things." P14, End-user*

A few implementors and end-users also suggested that further expanding the DCT tool by partnering with external bodies, such as local public health units and other hospitals in the region, would be beneficial. One stated *"... organizations can learn from each other, as to sort of what the best tool is" (P01, End-user),* which highlights the need for knowledge sharing to avoid *"duplicated efforts."* This way was further supported by an implementor identifying that partnering with regional hospitals would have made contact tracing processes *"... a little bit more standardized and just a bit quicker" (P12, Implementor).*

Area of Improvement Summary

Participants among the stakeholder groups identified several areas of improvement for the DCT tool. Key recommendations centered on enhancing the simplicity and user-friendliness of the technology. Specifically, a few occupational specialists and end-users noted the importance of having short and relevant questions. Additionally, one end-user suggested that modifications to the DCT tool's design would improve its aesthetics. For easier data reporting, implementors and occupational specialists recommended that the format of questions should be standard responses.

Collectively, participants across the stakeholder groups also recognized the need to improve staff access to the DCT tool. End users suggested integrating the DCT tool into the hospital's network through a clear icon, while implementors noted exploring alternative methods to deliver the DCT tool, such as SMS messages. Training and education were deemed essential for both end users and back users of the DCT tool. The implementors advocated for educating staff on general contact tracing practices, such as safety implications. Several participants also suggested that advanced communication surrounding the DCT would have been beneficial. Implementors suggested that having instructional videos, tip sheets, and FAQs may have helped end-users understand the rationale for its use. However, occupational specialists highlighted the importance of aligning communication strategies with the standard practices of the target audience. For frontline HCWs, it was suggested to place more emphasis on in-person communication rather than email-based communication.

Implementors and occupational specialists also highlighted the potential benefits of additional training opportunities for the back-users of the DCT tool. They proposed increasing the number of personnel who could support the DCT initiative and potentially switching to platforms that could be managed internally. Implementors and occupational specialists also discussed the integration of EMRs and other hospital information systems within the DCT tool as a future possibility. Although advancements within these areas were acknowledged to be ongoing, it was noted that health technology is not yet mature enough to support such efforts. End users also suggested that the DCT tool could be distributed to patients and caregivers should they have potential COVID-19 contact at the hospital. Moreover, another end-user suggested that the DCT tool should be incorporated if the hospital is taking proactive measures to prevent COVID-19 transmission. Last, participants suggested that collaboration with external entities

such as local public health units or other hospitals in the region could improve DCT practices. Specifically, such cross-collaboration was perceived to foster improvement in the management of infectious diseases and prevent duplicated efforts. Table 6 summarizes the areas of improvement related to the DCT tool as well as the broader DCT practices as recommended by participants.

Table 7. Summary of Areas of Improvement

Problem	Recommendation
Usability	• Shortening length of tool • Reviewing questions to ensure relevance • Intuitive design • Inclusion of drop-down menu's rather than free text • Improving aesthetics
Accessibility	• Easy-to-access icon on hospital intranet, videos explanations, tip sheets, and "how-to" processes • Linking to SMS systems • Always available to staff
Education/Training	• Advanced communication to staff • Rationale and importance of tool • Adapting education/communication aligned to frontline staff practices • Enhancing internal expertise • Providing training for team supporting tool
Integration/Expansion	• Clinical systems • Additional proactive safety mitigations • Public health and regional hospitals

Discussion

Principle Findings

This exploratory qualitative study is among the first to present in-depth insights into the use of a DCT approach from the perspective of hospital leaders and HCWs. The application of DCT in the hospital context has not only lagged behind the community setting during the COVID-19 pandemic, but limited evidence exists on its use performance and acceptability in real-world settings (Chambers & Anglemyer, 2022). This stems from the primary emphasis on quantitative outcomes related to hospital-based DCT, rather than on understanding the processes and mechanisms through which these technologies are implemented and how uptake is achieved. The present study fills this gap by exploring hospital stakeholders' perspectives on the adoption,

implementation, and outcomes of a web-based DCT tool used extensively within a specialized acute pediatric hospital in Ontario throughout the COVID-19 pandemic.

Sustaining contact tracing enhances the hospital's capacity to maintain a safe healthcare environment (Breeher et al., 2020). Considering the findings presented in this study and weighing the challenges and benefits, the use of DCT in a hospital context offered several positive outcomes. First, the use of the DCT tool offered an efficient and resource-friendly way to conduct contact tracing during the COVID-19 pandemic. The DCT tool analyzed in this study provided a structured format for reaching potentially exposed staff, leading to several benefits at the individual and organizational levels. Second, the findings highlight that the educational component embedded in the DCT tool was highly valued. This information promptly guided staff on quarantine procedures and testing information after being identified as a close contact. Third, the DCT approach enabled feasible contact tracing during the pandemic crisis. By utilizing a structured and standardized process, the DCT tool proved to be instrumental for rapidly implementing infection control and outbreak measures in the hospital. Last, the DCT tool's perceived positive outcome on safety not only contributed to maintaining a low nosocomial infection record at the hospital but also extended beyond the hospital, yielding broader implications for community safety. Therefore, considering these advantages, implementing web-based DCT approaches is advisable for future use of infectious disease management in this context.

A strength of this study lies in its focus on the various perspectives of stakeholders involved with the DCT tool in different capacities, providing a substantial amount of rich data and contextual findings. A strength of this study lies in its focus on the various perspectives of participants involved with the DCT tool in different capacities, revealing commonalities and distinctions among the stakeholder groups. There was notable alignment among stakeholders' perspectives throughout the analysis and within the RE-AIM dimensions. The majority shared similar views regarding the advantages of utilizing the DCT tool amid the COVID-19 crisis. A common theme in participants' perspectives was that the DCT tool, alongside the other prevention measures employed at the hospital, held safety benefits for all individuals entering the hospital. This was perceived from the standpoint of HCWs, patients, caregivers and families. Furthermore, participants universally recognized the challenges related to conducting contact tracing through a web-based approach. These challenges primarily stemmed from technological

limitations, potential biases in responses, and the risk of losing nuanced information during case investigations. Despite these acknowledged limitations, stakeholders agreed that the approach to monitoring infectious diseases could be scaled up and seamlessly integrated into the hospital's routine practices. In the following section, I summarize additional key findings related to this study, highlighting pertinent differences in perspectives among the stakeholder groups included in this study. Last, I present the broader contributions stemming from this study, and its potential relevance for both practitioners and researchers.

RE-AIM Findings

Did the Digital Contact Tracing Tool 'Reach' the Target Audience?

Overall, the study's findings suggested that the DCT tool had a broad reach to various hospital staff, including learners, volunteers, support staff, and medical staff. Stakeholders primarily held similar perspectives when describing that staff engagement was facilitated by healthcare professionals' self-accountability to follow safety procedures, working within a pediatric hospital, and the convenience of utilizing technology as opposed to answering a phone call for contact tracing. However, implementors and occupational specialists largely held the perspective that the initial fear of COVID-19 exposure among frontline staff subsequently influenced them to actively seek information through the DCT tool. End-users did not hold this perspective; rather, they highlighted the importance of acquiring awareness about COVID-19 exposures to protect both their well-being and that of others, whether in their personal lives or the clinical environment. All stakeholder groups identified potential difficulties with technology access and the potential consequences of completing COVID-19 risk-assessments. Notably, while end-users did not specifically mention this factor to be a barrier, participants expected such obstacles would have existed among the broader organization.

What was the Perceived 'Effectiveness' of the Digital Contact Tracing Tool?

Reported Positive Outcomes

Stakeholders overwhelmingly showed that the DCT approach described in this study was agile enough to accommodate the evolving case and contact management guidelines throughout the COVID-19 pandemic. The use of the DCT approach was also perceived to be of value for reaching staff promptly, the ability to scale resources while managing large-scale case investigations, and the capacity to inform decision-making at the individual and organizational

level from structured data collection. These results are in line with studies suggesting that technology use increases the scalability and efficiency of contact tracing compared to traditional approaches (Braithwaite et al., 2020; Breeher et al., 2020; Golinelli et al., 2020; Huang et al., 2020; Zirbes et al., 2021)

Several implementors and occupational specialists shared similar perspectives that the DCT tool enhanced the efficiencies of contact tracing, which was especially critical during periods of heightened transmissibility. By streamlining processes through the tool, a particularly positive outcome was that a relatively small team of nurses could successfully manage an extensive demand for COVID-19 case investigations. There was also consensus among implementors and occupational specialists regarding the DCT tool's ability to adapt to changes in hospital policies and procedures during the rapidly evolving COVID-19 situation.

Standardizing data collection during contact tracing was also a major theme underscored in the findings. Implementors described the important role of these data for reporting COVID-19-related data to the appropriate external entities, including Ottawa Public Health and the MOHLTC. However, at the internal level, several implementors and occupational specialists viewed this outcome of the DCT tool as essential for informing policies and preventive measures within the hospital. In addition to quickly identifying and reaching staff regarding their probable exposures, identifying the areas where risk-mitigation strategies could be implemented was perceived to have substantial impacts on the hospital's low outbreak record. Overall, these findings echo that DCT approaches can facilitate the management of surveillance data, improve manpower utilization, and reduce transmission rates within the hospital context (Abdul Muthalib et al., 2023; Bechmann & Geginat, 2022; Braithwaite et al., 2020; Breeher et al., 2020; Venkataraman et al., 2020; Zirbes et al., 2021).

Reports detailing the DCT approach have also found that timely notification of HCWs regarding their exposures can potentially mitigate COVID-19 impacts among patients, units, and the broader community by reducing COVID-19 transmission (Bailie et al., 2021; Breeher et al., 2020; Llupià et al., 2022). However, this work goes further to suggest that timely contact tracing can also influence the practices of HCWs, including decision-making at the clinical level and in their personal lives. The HCWs within the present study also recognized that the embedded guidance and automated responses not only delivered education but also contributed to staff recognizing their own risk of COVID-19 exposure. This was perceived to lead to changes in

behavior in the clinical environment and within their personal lives. However, this finding may be attributed to the educational resources and automated responses embedded into the DCT tool rather than the mere use of a DCT approach.

Reported Negative/Unintended Outcomes

Although this innovative approach to contact tracing yielded positive outcomes, participants also recognized the limitations and challenges. It is essential to acknowledge that the DCT approach (internet-based tool and EMR review) used in this study faced its own set of complications. Participants suggested that staff may have been hesitant to report COVID-19-related information, alongside the challenges related to recall and favorability biases. In combination, such factors potentially lead to inaccuracies in the data collected by the DCT tool and consequently may have led to inaccurate risk-assessments or adherence to infection control practices in the hospital. Similar issues related to such self-reported biases have been highlighted in the literature for both digital and traditional approaches of contact tracing (Hong et al., 2021; Klompas et al., 2021; Ochoa-Leite et al., 2021).

Compared to traditional contact tracing, participants in the present study expressed that nuanced information on the dynamics of staff interactions could not be entirely conveyed through the DCT tool. This finding also aligns with some of the limitations noted in similar web-based DCT approaches reported in the literature (Breeher et al., 2020; Ho et al., 2020; Hong et al., 2021; Zirbes et al., 2021). A minority perspective among stakeholders was that the other preventative mitigations and policies employed during COVID-19 have a more substantial influence on reducing transmission than contact tracing efforts. Last, the findings also highlight that the safety impacts of the DCT tool were complemented by using other prevention measures, such as universal PPE, distancing measures, entrance screening, and accessible testing. This finding reinforces the idea that there is a need for a comprehensive approach to disease surveillance and prevention within the healthcare context.

What Factors Influenced the 'Adoption' of the Digital Contact Tracing Tool?

The findings also revealed that the adoption of the DCT tool was generally high, which contrasts with what has been reported on the uptake of DCT approaches facing the community setting during the COVID-19 pandemic (Vogt et al., 2022). The possible reason for this

discrepancy may be explained by HCWs' perceived ease of use of the technology, coupled with their desire to be aware of COVID-19 exposures and the influence of working within a children's hospital. Participants among the stakeholder groups also attributed adoption to the presence of well-established and trusted nurses behind the DCT tool.

Research on technology adoption and the intention to use technology is a commonly studied area within healthcare. As such, various research models have been used to understand the different factors that can influence the decision or intention to adopt technology. Commonly discussed models in the technology-adoption healthcare literature include the Technology Acceptance Model (TAM) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). The findings of this thesis research also align with the constructs of the TAM and UTAUT. Specifically, end-users' beliefs on the ease of use of the DCT tool; attitudes toward new technologies and using the DCT; the ability to use the DCT tool; the usefulness of the DCT tool; the facilitating conditions (technical and organizational) of the DCT tool; and the perceived importance of contact tracing to others.

Furthermore, a major barrier to the adoption of the DCT tool as perceived by all stakeholder groups was that its delivery was not well-suited to the established practices of frontline HCWs, given their infrequent use of email and rotating shift schedules. Although no studies have specifically reported this misalignment of HCWs' adoption of DCT technologies, prior research examining HCWs' technology adoption is commonly hindered by perceived disruptions in their workflow (Gagnon et al., 2016). Implementors and occupational specialists also shared that this misalignment was pronounced in specific clinical areas and among frontline medical professionals, such as nurses and physicians. However, this perspective was not shared by the end-users, despite this stakeholder group having a diverse representation of frontline medical professionals.

It was also noted that frontline medical staff members' willingness to complete the DCT tool in the later stages of the pandemic declined. This may be explained by a perceived diminished threat of COVID-19, which may be explained by an increase in community-acquired COVID-19 among HCWs and the discontinuation of public health measures (Mitchell et al., 2023). Importantly, this finding may not be exclusive to the application of DCT and could have relevance to traditional contact tracing approaches as well. However, this observation has not yet been accounted for in the existing literature.

How was Digital Contact Tracing 'Implemented'? Was it Delivered as Intended?

The implementation of the DCT tool was influenced by the need to maintain COVID-19 compliance with external entries, maximize contact tracing efficiencies, and foster trust and confidence among staff during a period of crisis. According to implementors and occupation specialists, the advocacy of technology by championing and innovative leaders was seen as the primary driver of implementation success. Indeed, these findings are consistent with previous literature exploring the influence of top-level leaders on championing technology use within healthcare organizations (Hsia et al., 2019). Furthermore, the strong buy-in from top-level leadership was perceived to have a cascading influence on the success of the DCT tool, which highlights that clinical leaders also play a crucial role in facilitating the adoption of new implementations (Morena et al., 2022). Another important factor in the success of the DCT tool as perceived by implementors and occupational specialists was the various expertise stemming from intrahospital and external partnership collaboration.

Stakeholder's perspectives concerning the DCT tool's implementation fidelity varied and were not universally shared. While some end-users expressed enthusiasm for the digital approach, others highlighted how the use of technology for contact tracing heightened anxiety, particularly during a time when frontline staff were already facing immense pressure due to the emergence of a novel virus impacting the healthcare system. Moreover, a minority perspective among end-users was the preference for a more personalized approach to contact tracing. It was recognized by implementors and occupational specialists that the DCT tool facilitated prompt guidance to staff, a task that would have been challenging if conducted solely through phone calls given the urgency of the COVID-19 situation. In this regard, similar findings on HCWs' initial resistance to web-based DCT approaches implemented in response to the COVID-19 pandemic have been reported in the literature (Wan et al., 2021). However, the present research extends this finding by describing the reasons for resistance and therefore represents a leading finding. Furthermore, it was perceived that some staff felt that they could only achieve the level of reassurance they needed from direct communication with the CST (e.g., phone calls). Consequently, the importance of offering human assurance regarding the implications of being exposed to infectious disease, instead of relying solely on technologies, during high-stress situations, is a principle finding. Collectively, these findings highlight the importance of

providing clear guidance and engaging in change management strategies before the implementation of new technologies.

What Adaptations Occurred to 'Maintain' Digital Contact Tracing? Can this Approach to Contact Tracing be Sustained Beyond COVID-19?

Overall, there was alignment between stakeholders sharing positive views on the maintenance and sustainability of the DCT approach. As reported by implementors and occupational specialists, the DCT tool's long-term use was fostered by integrating iterative improvements and shifting its delivery during periods of increased transmissibility. While most stakeholders viewed the DCT positively and advocated for its continued use based on its generated safety outcomes, it was also recognized by some stakeholders that the technology needed improvements to remain sustainable. A minority perspective held by a few stakeholders was that the practice of contact tracing for COVID-19, including the distribution of the DCT tool, should be discontinued within the hospital based on its diminished value.

Although the DCT tool analyzed in this study was discontinued during the write-up process, it is noteworthy that most stakeholders reported that the DCT tool serves as a foundation to integrate routine practices for infectious disease monitoring. It was widely recognized that the use of the DCT tool has the potential to contribute broad system impacts, as it could be quickly adapted to address any infectious disease of concern. However, the findings suggest that ensuring the transferability of DCTs beyond COVID-19 will require persistent leadership, appropriate financial resources, and scientific evidence. Furthermore, the findings related to the maintenance dimension begin to highlight actional directions for DCT improvement, which are presented below in the "Practice and Research Implications" section.

Practice and Research Implications

Practice. The findings presented in this thesis contribute to evidence-based practices in the area of technology and infectious disease management within the hospital context. As such, the findings provide practical guidance for policymakers, hospital administrators, or technology developers who wish to scale up initiatives focused on DCT implementation, design, and/or refinements within this environment.

One fundamental aspect to address pertains to the enhancement of the DCT tool itself, to ensure efficient data entering, cleaning, and processing (Kannangara et al., 2021). Implementing

a more user-friendly interface and design could enhance the ease of use for end-users. Future hospital administrators and technology developers may consider employing more select-response formats in internet-based survey DCT approaches, such as drop-down menus. By reducing the dependency on the quality of the data entered, addressing this limitation could also alleviate some of the manual burdens experienced by the backend users. Furthermore, the simplification of data entry will also facilitate more accessible data extraction for organizational decision-making. As such, the availability of more uniform data may also be desired for future research purposes.

It was also recommended that questions asked within the DCT tool should be presented in a manner that is simple and less time-consuming. To support this, hospital administrators and technology developers consider the length and duration needed to complete the risk-assessment, the overall presentation and appearance of the technology, and the inclusion of straightforward language. To fit the needs of the target audience, it may also be pertinent to explore the possibility of making the DCT tool available in multiple languages and avoiding complex medical terminology. Furthermore, clear contingency plans need to be established in case staff do not have access to the proper technology to initiate the DCT tool or if issues permit with the language and terminology of the tool.

The findings also reveal several practice implications for increasing DCT uptake among staff. Regarding the access of the DCT tool, it was suggested to develop readily available links to the DCT tool for all staff by implementing clear and intuitive icons and "need-to-know" pages on the hospital intranet. Another main aspect is related to change management and how to increase uptake among frontline staff. Here, it was suggested that additional education on the importance of contact tracing and monitoring infectious diseases within the context of a hospital. Recommendations also suggested that investing in accessible training efforts, such as video explanations, responses to frequently asked questions, scheduled training sessions, and access to on-unit support would be beneficial. However, as highlighted in the findings, it is important to consider that education must be delivered to frontline HCWs in a way that best aligns with their standard work practices. In this regard, more emphasis on in-person communication was suggested.

Pandemic Preparedness. As COVID-19 transitions into an endemic phase, the lessons learned over the last two years will be a crucial component in preparing and planning for future

pandemics (Loveday & Wilson, 2021). The innovative approach to monitoring COVID-19 exposures presented in this study sets the stage for larger projects aimed at improving HCW screening or surveillance within the hospital context. Most participants in this study advocated \ sustaining the DCT approach beyond the pandemic and into other infectious disease contexts. However, this study echoed findings reported in literature, revealing the limitations of detecting interactions between hospital staff who do not require access, or have limited access to the EMR (Breeher et al., 2020; Hong et al., 2021).

Given that the DCT approach employed in this study still required multiple manual steps, exploring how existing clinical systems (e.g., EMRs and human resource systems) can be appropriately and securely integrated into DCT approaches is of relevance. This may not only work to capture staff-to-staff and staff-to-patient interactions with greater accuracy but also to minimize the manual burdens for those conducting contact tracing. Additionally, a notable finding of the present study is that the widespread distribution of the DCT tool was perceived to present an information overload for staff over time. It was recommended that distributing the DCT tool to individuals at the highest risk of COVID-19 exposure could improve sustained participation levels.

Collectively, these findings underscore the importance of future advancements related to integration not only within the existing hospital information system but also with complementary contact tracing approaches. For instance, hospital administrators may wish to explore the potential of incorporating passive monitoring technologies, such as RTLS or Bluetooth, high-quality data sources (e.g. EMRs), in addition to web-based DCT to improve the efficiency and accuracy of contact tracing (Aung et al., 2023; Ho et al., 2020, 2020; Hong et al., 2021). Therefore, a crucial next step for hospital administrators is planning for, communicating about, and investing resources into larger-scale DCT initiatives during the post-pandemic planning period.

Research. This study serves as a foundation for future research to develop and investigate aspects related to the findings. Researchers have emphasized the importance of establishing a collectively agreed-upon set of indicators to facilitate comparisons and improvements related to contact tracing efforts (Amicosante et al., 2023). The findings from the present study hold unique insights, as they present hospital stakeholders' perceived indicators of DCT effectiveness. These indicators primarily fell into three domains: (1) staff's engagement

and responsiveness with technology, (2) an extensive scope of infection indicators, and (3) technical operations, including the user-friendliness of technology and its capacity to meet organizational needs. While some of these indicators are more applicable to the web-based DCT approach analyzed in this study, these indicators offer valuable guidance for both practice and policy considerations in the field of technology advances for HCW screening and surveillance. Furthermore, expanding on these efforts may facilitate the development of a practical framework for assessing the quality of DCT approaches. This may be appropriately addressed through Delphi methodologies, which allow a group of key stakeholders and experts to work toward establishing a consensus (Dalkey & Helmer, 1963). Researchers may consider soliciting a panel of infectious disease experts, technology or software developers, personnel conducting contact tracing, end-users of such technologies, and researchers.

Although all participants in this study were questioned about the facilitators and barriers to engaging with and adopting the DCT tool, participants in the implementor and occupational specialist stakeholder group frequently had more insights to provide than end-users. This could be attributed to their roles and involvement with the DCT tool. Furthermore, I aimed to best align the findings within the dimensions of the RE-AIM. As ‘reach’ in the present study addressed the individual-level factors influencing engagement with the DCT tool, the insights offered by the end-users appropriately addressed this dimension. Whereas implementors and occupational specialists contributed substantially to the 'adoption' dimension, providing a more nuanced understanding of the organizational-level factors that influenced the DCT tool's uptake. Despite this distinction enabling a holistic view of the factors influencing the engagement and uptake of the tool within the individual and organizational context, future research could explore the dimension of ‘adoption’ using quantitative methodologies with a larger and more representative group of end-users. This could entail the assessment of staff acceptance through established theories, such as the TAM or UTAUT. Additionally, exploring staff confidence in the hospital's response to COVID-19 and their overall satisfaction with the employed DCT tool proposes a viable avenue for further study using quantitative methods. A more in-depth examination of the demographics of staff members who consistently completed the tool, including professional-related details, presents an intriguing proposition to address ‘reach’ in subsequent studies.

The findings also present an opportunity to further explore the distinguishing factors related to the outcomes specifically related to the use of technology for contact tracing, as

opposed to traditional approaches. Additionally, future studies may wish to consider understanding and separating the outcomes specifically related to the technologies used for contact tracing, from the dissemination of guidance provided within these approaches.

Last, the RE-AIM framework has been historically used to design, implement, and evaluate health promotion initiatives. This study helps extend the literature on the pragmatic uses of the RE-AIM framework by demonstrating a qualitative application of the framework in a digital healthcare context. Specifically, the use of RE-AIM represents a practical approach to disseminating research into practice (Holtrop et al., 2018), and sheds light on technology adoption, scalability, implementation challenges, and sustainable use in this context.

Limitations

There are some limitations to acknowledge concerning this research. First, this study is based on the experiences at a single hospital with a single DCT approach. Thus, the findings may not be representative of other hospitals and other DCT approaches and therefore must be interpreted and transferred with caution. Although the RE-AIM framework can stimulate knowledge transfer into practice (Glasgow et al., 1999), a range of dynamic and challenging measures can influence the ability of the present study to be transferred to different hospital contexts during a pandemic scenario. This may include factors such as the influence of HCWs' compliance with infection control, institution-related influences such as definitions of close contacts, and disease factors (Bailie et al., 2021).

Although the purposeful sample used for the qualitative inquiry of this study was warranted, the study sample is not representative of all hospital stakeholders. As issues persisted with recruiting HCWs, it was not possible to provide a comprehensive understanding of the perspectives of staff with limited willingness to engage with the DCT tool. Therefore, capturing the perspectives from a broader range of frontline HCWs – including various medical professions and other support staff – may serve as the foundation for future work (see the "Practice and Research Implications" section above). Furthermore, it is important to note that some participants were directly involved in the implementation of the DCT tool, which may have limited their exposure to alternative approaches to contact tracing during the COVID-19 pandemic. This potential lack of a comparative perspective may have introduced bias in some participants' feedback and perspectives related to the DCT approach explored in the present

study. It is also important to note that the data collection for this study commenced almost three years after the DCT tool had been implemented at the CHEO. As a result, some recall biases among participants may have been present.

Additionally, at the beginning of data collection, the Ottawa region, and subsequently CHEO, was seeing an increase in hospitalizations related to RSV and influenza. In addition, pandemic pressures were placed on the health system from the surging Omicron variant. Furthermore, towards the later stages of data collection (February 2023), the MOHLTC started easing public health measures. Given these circumstances, it is possible that participants' perspectives of the DCT tool may have been reflective of the evolving changes and final acute stages of the pandemic. However, to mitigate this challenge, the interview guides used in this study prompted participants to reflect on the tool's implementation and its initial outcomes, in addition to its current status and sustainability. As a result, the findings and conclusions of this research provide an accurate reflection of the evolving COVID-19 situation and participants' perspectives.

Due to challenges related to time constraints and data accuracy during the study period, it was not possible to triangulate data collection methods (e.g., data collected from the DCT tool), which could have helped strengthen the results. Last, with all qualitative studies, possible researcher bias could have occurred. To mitigate the effects of this bias, steps were taken to reflect on the decisions and conclusions that were drawn from the data (see “Quality” section).

It is important to address that some of the positive and negative outcomes reported in this study may be inherent to the practice of contact tracing, as opposed to being specifically related to the DCT approach. Considering that HCWs are often concerned about contracting viruses when working amidst a pandemic crisis (Billings et al., 2021), the findings presented in this study may not be directly tied to DCTs, but instead to the broader practice of contact tracing in the hospital context. Similarly, certain negative barriers and challenges reported in this study, such as staffing impacts, may have arisen irrespective of the implemented DCT tool. For instance, similar findings of furloughing staff through contact tracing exercises and subsequent implications on staffing capacity have been reported with the use of traditional contact tracing methods (Harada et al., 2020). However, it could also be argued that the increased efficiencies related to the DCT approach potentially led to a more accurate identification of high-risk contacts compared to traditional contact tracing approaches. Consequently, the downstream

impact of furloughing more staff had negative implications for the hospital's overall capacity to provide patient care. Comparable findings related to false-positive notifications with the use of EMR data for contact tracing have been reported in the literature (Hong et al., 2021).

Conclusion

Contact tracing has been a key response to controlling outbreaks of infectious diseases across health systems throughout the COVID-19 pandemic. As healthcare environments tend to have inherent close contact, contact tracing holds prominence for maintaining a safe environment for both vulnerable patient populations and frontline HCWs during infectious disease outbreaks. Nonetheless, traditional approaches to contact tracing have proven to be inadequate in responding to the challenges imposed by the COVID-19 pandemic. Consequently, various innovations and technologies have been implemented to augment a more efficient contact tracing process. Early research in this area has provided valuable insights into the efficiencies of various DCT tools; however, has lacked the ability to offer a comprehensive understanding of the perspectives of adopters regarding the benefits and challenges encountered with such technologies.

Underpinned by a well-known framework to translate research into practice, this qualitative research presents the experiences of various hospital stakeholders with the adoption, implementation, and outcomes of a web-based DCT tool used for managing HCWs' exposures to COVID-19 in specialized acute-care pediatric hospital in Canada. The implementation of the DCT tool was influenced by several key factors: the imperative to maintain regulatory COVID-19 compliance, the drive to maximize contact tracing efficiencies, and the goal of fostering trust among staff amidst the pandemic crisis. Successful implementation was strengthened by innovative leadership and collaboration. Furthermore, the DCT tool's ability to increase awareness of probable COVID-19 exposures and its user-friendly functionality increased its reach among staff. Stakeholders generally recognized that the DCT tool's impact was the capacity to enable a timely and agile response to COVID-19, and many valued its broad safety contributions. Conversely, stakeholders also identified complexities and unintended outcomes that were experienced with the use of a web-based DCT tool. Particularly, this included the loss of nuanced information occurring from electronically conducting risk assessments and other limitations of the platform utilized for contact tracing. Additionally, challenges related to the

alignment and delivery of DCTs, alongside the evolving perspectives of COVID-19, posed obstacles to continued adoption by HCWs.

The study has revealed substantial benefits, and despite the challenges identified, the overall positive outcomes underscore its potential value. The findings reveal several practical implications for refining and sustaining the digital approach to contact tracing beyond COVID-19. These results hold valuable insights that may help inform response measures in the post-pandemic period and present benchmarking results at the policy and research levels.

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Contact of a COVID-19 Positive Case

Please complete the survey below.

Thank you!

Today's date _____

I am completing this survey for a possible:
- ◯ COVID Positive Staff/Student Contact
- ◯ COVID Positive Patient Contact
- ◯ COVID Positive Parent/Caregiver Contact

Please complete the survey to the best of your ability. COVID Safety Team will be in contact with you. Thank you.

Statement: Someone in your workplace has tested positive for COVID-19, and you have been identified as someone they had possibly come into contact with. If you have NOT had contact with this person, please answer the first question and close the survey.

Statement: A patient/person in your workplace has tested positive for COVID-19. You have been identified as someone who was working in the department on the day the patient/person was there, and who may have come into contact with them. Please fill out the following questionnaire.

Please enter Case #

(Provided to you by OHS) _____

Your Name: _____
(Please enter your first and last name.)

Phone Number: _____

Email: _____

Manager/Supervisor: _____

Position/Role: _____

Department/ Division _____

Have you tested positive for COVID in the last 90 days?
- ◯ Yes
- ◯ No

General: (all questions asked in relation to last known contact day as per case identified and 48 hours prior to their symptom onset). Please answer all questions	
1: Did you have any contact with this positive case?	◯ No ◯ Yes ◯ I am not sure
1a. Are you fully vaccinated for COVID-19?	◯ No ◯ No, I've been partially vaccinated ◯ Yes, I've been fully vaccinated
2. Is there anyone else who had contact with this person and may not show up on our line list (ex: would not have signed into Epic or shown up on the assignment sheet- volunteers, students, interpreters, food services, etc)?	◯ No ◯ Yes
2a. Please specify:	_____
3. Please specify what PPE you were wearing with all interactions with the positive case (click all that apply)	☐ Eye Protection ☐ Gloves ☐ Gown ☐ N95 respirator ☐ Procedural mask ☐ Mask with visor ☐ Additional information ☐ No PPE worn
3a. Please specify	_____
4. Was there any known breach in your PPE during any positive case interactions on your shift this date?	◯ Yes ◯ No
Thank you. You have indicated you have not had contact with this positive case. No further follow-up is required. Please feel free to leave any comments.	
5. When was your last day of contact with the positive case?	_____

6. Do you have any of the listed symptoms at this time Check all that apply	☐ fever ☐ chills ☐ cough ☐ sputum production ☐ difficulty breathing ☐ sore throat ☐ rhinorrhea ☐ unexplained fatigue/malaise ☐ delirium (acutely altered mental status and inattention) ☐ falls ☐ acute functional decline ☐ exacerbation of chronic conditions ☐ nausea/vomiting ☐ diarrhea ☐ abdominal pain ☐ headache ☐ conjunctivitis ☐ loss of taste ☐ loss of smell ☐ tachycardia (increase in heart rate) ☐ hypotension (decrease in blood pressure) ☐ None
7. If you have symptoms, when did they begin?	_____
8. Have you been tested because of these current symptoms?	◯ Yes ◯ No
9. When was your testing done?	_____
10. Testing Result	◯ I don't have my result ◯ COVID-19 Detected ◯ COVID-19 Not Detected

Work History:

1. Did you have any close interactions with the positive case? (less than 2m proximity for greater than 15 minutes cumulatively over the past 24 hours)	◯ Yes ◯ No ◯ I am not sure
1a: Please specify	_____
2. Is there anyone at work who you are in close contact (within 2 metres) regularly?	◯ Yes ◯ No
2a. Is there anyone at work who you are in close contact (within 2 metres) regularly WITHOUT PPE? Please specify:	_____
2. Were you wearing appropriate and consistent PPE during your interactions with the positive case (i.e. patients/staff)?	◯ Yes ◯ No ◯ I am not sure

3. Was there any known breach in your PPE during your interaction with this individual (e.g. glove broke, forgotten item)?	◯ Yes ◯ No ◯ I am not sure
3a. Was there any known breach in your PPE? Please explain:	_____
4. At any time during your interaction with the positive case, were there any aerosol-generating medical procedures (AGMP) performed? (Endotracheal intubation/ removal, including during cardio-pulmonary resuscitation, cardio-pulmonary resuscitation (CPR) during airway management (e.g. manual ventilation), open airway suctioning, bronchoscopy (Diagnostic or Therapeutic), sputum induction (Diagnostic or Therapeutic), non-invasive positive pressure ventilation for acute respiratory failure (CPAP, BiPAP), high flow oxygen therapy, insertion or removal of laryngeal mask airway (LMA).	◯ Yes ◯ No
4a. If so, please specify which type of eye protection you were using. If you were wearing goggles, please specify the exact type of goggles. Please note that Zenni and Stoggles are not appropriate eye protection for AGMP or splashes.	_____

Additional Information

Are there any comments/processes or practices that you feel need to be improved related to the management of this covid positive case?	_____

HIDDEN FIELDS

Are there any processes or practices that you feel need to be improved related to the management of this covid positive case?	_____
OHS Email	_____
1. Do you suffer from any chronic conditions that can mimic the signs and symptoms of COVID-19?	◯ Yes ◯ No
If yes, please describe these symptoms. *Please note - in order to maintain your privacy, you do not need to reveal your condition. Simply describe your symptoms.	_____

2. Have you needed medical consultation for any of these symptoms?	_____
Please give a few details to confirm who this relates to:	_____
6. Where was your testing done?	_____
If applicable, do you recall if the parents were wearing their mask during their time at CHEO?	◯ Yes ◯ No ◯ Unsure
2. Role at other place of work:	_____
Do you recall if the positive case was wearing their mask during their time at CHEO?	◯ Yes ◯ No ◯ Unsure
What was your last vaccination date?	_____
4. Do you have any other symptoms that are not listed above?	◯ Yes ◯ No
7. If tested, have you notified Occupational Health of your testing/of your results	◯ Yes ◯ No
Were you wearing appropriate and consistent PPE during any interactions with any patient/person on your shift this date?	◯ Yes ◯ No
2. Are you working anywhere else at this time?	◯ Yes ◯ No
1. Are you aware of who the positive case is?	◯ Yes ◯ No
4. Please specify other symptoms:	_____
8. If symptomatic, have you been self-isolating since your symptoms began?	◯ Yes ◯ No ◯ N/A - not symptomatic
6. What prompted the testing?	_____
1. Were you working on the dates listed in the e-mail?	◯ Yes ◯ No

2. If so, what was your last date of work?	_____
2. Other place of employment:	_____
2. Department/Unit at other place of work:	_____
3. If working elsewhere, are you aware if this institution/unit was considered to be in an "outbreak" status?	◯ Yes ◯ No
4. Please specify what PPE were you wearing during your interactions with this patient/staff. (Click all that apply)	☐ Eye Protection ☐ Gloves ☐ Gown ☐ N95 respirator ☐ Procedural mask ☐ Mask with visor ☐ Additional Information
4a. Please specify.	_____

Appendix B: Interview Guides

Stakeholder Group 1: Actors Involved in Implementation of the DCT tool[3].

INTRODUCTION:

1. To start this interview, I would like to get some brief information on your involvement at CHEO.
    a. What is your role at the hospital?
    b. How long have you been in this role?
    c. Can you describe your role in the contact digital tracing initiative?

REACH:

1. What was the target population identified to use the digital contact tracing tool?
    a. Were there any strategies used to engage the target population to use the digital tool?
2. Who do you believe benefits from CHEO using the digital tool for contact tracing? (i.e., staff? Patients?)

EFFECTIVENESS:

1. From your perspective, what would you consider an effective digital contact tracing strategy to be?
    a. What specific dimensions and measures would you consider if you were to assess the effectiveness of digital contact tracing?
2. Given your experience, do you consider the digital contact tracing implemented at CHEO to be effective?
3. In your opinion, what have been the main *benefits* of using the digital tool for contact tracing?
4. In your opinion, what have been the main *challenges* of using the digital tool for contact tracing?

ADOPTION:

1. In your opinion, do you believe the organization was successful in adopting a digital tool for contact tracing?
    a. If so, what factors do you think contributed to the organization adopting the digital tool? (e.g., *facilitators*)
2. Are you aware of any barriers that may have prevented the adoption of digital tool used at CHEO? If so, what were they?
    a. In your opinion, how do you think these can barriers be addressed?

IMPLEMENTATION:

1. Could you please describe how the decision was made to implement the digital strategy for contact tracing?
    a. Who was involved in the implementation of this tool?
    b. What were the steps required to implement the digital contact tracing tool?
2. How do you think staff initially viewed the implementation of the digital tool? Do you think that has changed over time?
3. Were there any underlying barriers to implementing the digital tool? If so, what were they?
    a. Would you recommend any strategies that organizations could employ to overcome barriers to implementation?

MAINTENANCE:

1. Has the digital contact tracing tool become established as a practice at CHEO? (e.g., institutionalized)? If so, how?
2. Do you think that the digital contact tracing tool is sustainable in its current form?
    a. From your point of view, is there anything that needs to happen to make the digital tool more sustainable?
3. Do you foresee CHEO sustaining this form of contact tracing in the future? If so, why?

LESSONS LEARNED AND RECOMMENDATIONS

[3] Text highlighted in blue represents the questions tailored specifically for the implementor stakeholder group.

1. Are there areas of improvement, regarding the implementation of such a tool, that you would recommend?
2. Given your involvement in this initiative, what would be your top three lessons learned in the process of implementing the digital tool at CHEO?
3. Is there any additional information that you would like to share on this topic?

Stakeholder Group 2: Actors involved in decision-making based on the DCT tool[4].

INTRODUCTION:

1. To start this interview, I would like to get some brief information on your involvement at CHEO.
    a. What is your role at the hospital?
    b. How long have you been in this role?
    c. Can you describe your role in the contact digital tracing initiative?

REACH:

1. What was the target population identified to use the digital contact tracing tool?
    a. Were there any strategies used to engage the target population to use digital contact tracing?
2. Who do you believe benefits from CHEO using the digital tool for contact tracing? (i.e., staff? Patients?)

EFFECTIVENESS:

1. From your perspective, what would you consider an effective digital contact tracing strategy to be?
    a. What specific dimensions would you consider if you were to assess the effectiveness of digital contact tracing?
2. Given your experience, do you consider the digital contact tracing implemented at CHEO to be effective? If so, how?
3. In your opinion, what have been the main *benefits* of using the digital tool for contact tracing?
    a. Do you think using digital contact tracing has played a role in maintaining infection control practices at CHEO? If so, how?
4. In your opinion, what have been the main *challenges* of using the digital tool for contact tracing?
    a. Thinking about the entire case management continuum, from index cases to following up with high-risk staff, which aspects have been most challenging to deliver via a digital tool?

ADOPTION::

What factors do you think contributed to the staff adopting the digital form of contact tracing? (e.g., facilitators)

1. Are you aware of any barriers that may have prevented the adoption of digital contact tracing at CHEO? If so, what were they?
    a. In your opinion, how do you think these can barriers be addressed?

IMPLEMENTATION:

1. What factors influenced the implementation of digital contact tracing?
    a. How do you think the use of a digital tool for contact tracing has been viewed by the organization? Do you think that has changed over time?
2. Has the digital contact tracing tool been adapted or modified throughout the pandemic? If so, could you please describe to me how and why adaptations have occurred?

MAINTENANCE: Do you think that digital contact tracing tool is sustainable in its current form?

[4] Text highlighted in green represents the questions tailored specifically for the occupational specialist stakeholder group.

a. From your point of view, is there anything that needs to happen to make the digital tool more sustainable?

2. Do you foresee CHEO sustaining this form of contact tracing in the future? If so, why?

LESSONS LEARNED AND RECOMMENDATIONS

1. Are there areas of improvement that you would recommend?
    a. What changes could be made to the digital tool to optimize its utility?
2. Given your involvement in this initiative, what would be your top three lessons learned from using the digital contact tracing tool for case and contact management?
3. Is there any additional information that you would like to share on this topic?

Stakeholder Group 3: Actors Involved as End-users of the DCT tool[5].

INTRODUCTION:

1. To start this interview, I would like to get some brief information on your involvement at CHEO.
    a. What is your role at the hospital?
    b. How long have you been in this role?
    c. Can you describe your role in the contact digital tracing initiative?

REACH:

1. Who do you believe benefits from CHEO using the digital tool for contact tracing?

EFFECTIVENESS:

1. From your perspective, what would you consider an effective digital contact tracing strategy to be?
    a. What specific dimensions would you consider if you were to assess the effectiveness of digital contact tracing?
2. Given your experience, do you consider the digital contact tracing implemented at CHEO to be effective? If so, how?
3. In your opinion, what have been the main *benefits* of using the digital tool for contact tracing?
4. In your opinion, what have been the main *challenges* of using the digital tool for contact tracing?
    a. What would you change about the digital tool if you were to avoid these challenges?

ADOPTION:

1. In your opinion, what factors may have facilitated your use of digital contact tracing? (Please provide an example).
    a. How easy is it to use digital contact tracing?
    b. In your opinion, what factors may have hindered your use of digital contact tracing? (Please provide an example).
2. In your opinion, what were the barriers (if any) that may have prevented the adoption of using this technology?
    a. Among the barriers, how do you think these can be addressed?

IMPLEMENTATION:

3. What has your experience been with the implementation of digital contact tracing during the pandemic?
    a. What did you expect in the beginning?

MAINTENANCE:

Evaluation Questions:

1. Do you think that digital contact tracing tool is sustainable in its current form?

[5] Text highlighted in red represents the questions tailored specifically for the end-user stakeholder group.

a. Do you think there is anything missing from the digital contact tracing tool? If so, what?

RECOMMENDATIONS

1. Are there any other areas of improvement that you would recommend?
2. Is there any additional information that you would like to share on this topic?

Appendix C: Ethical Forms

Children's Hospital of Eastern Ontario Research Institute Ethics Board Approval

CHEO REB
Letter of Approval

REB Protocol No: 22/114X
ROMEO File No: 20221354
Principal Investigator: Dr. Charles Hui
Protocol Title: CHEOREB# 22/114X - Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study

Protocol Status: Active

Approval Date: October 14, 2022
Approval Expiry Date: September 15, 2023

The CHEO REB has conducted a delegated review and determined that the conditions of approval have been satisfied for the above-named study. Approval is valid for the period indicated above. This research study is to be conducted by the investigator noted above. Annual renewals or study closures must be completed before the expiry date noted above.

REB members involved in the study do not participate in the review, deliberations, or decision.

Documents Approved:

Document Name	Comments	Version Date
Consent Form	Updated consent form, version date 30Sep22, clean copy	2022/09/30
Questionnaire/Survey	Interview protocol, version date 23Aug22	2022/08/23
Recruitment Materials	Updated recruitment email, version date 29Sep22, clean version	2022/09/29
Other Document	Updated cover letter, version date 30Sep22, clean version	2022/09/30
Protocol	Updated protocol, version date 30Sep22, clean copy	2022/09/30

University of Ottawa Research Ethics Board Approval

Dear Brynn O'Dwyer,

Please find attached the letter of administrative approval for your research project titled "Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study ".

This approval is valid until 15-09-2023 (corresponds to the date of the Primary REB). In order to keep your file up to date, please submit a copy of all modification requests, project renewals, and/or other relevant documents submitted to and approved by the Primary REB, as they become available.

Funded research: A reminder that you must provide a copy of this letter to Research Management Services.

If you have any questions, please contact the Ethics Office at ethics@uottawa.ca or by telephone at 613-562-5387.

You can view your project at any time by logging into eReviews.

Best regards,

Catherine Paquet
Director

This is an automated message. Please do not reply directly to this email.

Amendment Ethical Approval (Children's Hospital of Eastern Ontario)

REB Protocol No: 22/114X
ROMEO File No: 20221354
Principal Investigator: Dr. Charles Hui
Protocol Title: CHEOREB# 22/114X - Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study

Protocol Status: Active

Approval Date: February 24, 2023

The CHEO REB has conducted a delegated review and approved the minor modification for the above-named study.

REB members involved in the study do not participate in the review, deliberations, or decision.

Documents Approved:

Document Name	Comments	Version Date
Protocol	protocol	2023/02/23
Other Document	Recruitment email, version date 23Feb23	2023/02/23
Consent Form	consent form	2023/02/23

Amendment Ethical Approval (University of Ottawa)

Dear Brynn O'Dwyer,

Thank you for submitting a modification request for your research project titled "Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study ".

These modifications are now covered under the certificate of ethics approval, valid until 15-09-2023.

If you have any questions, please contact the Ethics Office at ethics@uottawa.ca or 613-562-5387.

You can view your project at any time by logging into eReviews .

Best regards,

Catherine Paquet
Director
Chair: Barbara Graves
REB: Comité d'éthique de la recherche en sciences sociales et humanités / Social Sciences and Humanities Research Ethics Board

This is an automated message. Please do not reply directly to this email.

Title of Study: Exploring Stakeholders' Perspectives of Digital Contact Tracing Implementation in a Hospital Context: A Qualitative Study

To Whom It May Concern,

We thank you for accepting to participate in this research project investigating digital contact tracing during the COVID-19 pandemic.

This Master's thesis project is conducted by Ms. Brynn O'Dwyer, under the supervision of Dr. Mirou Jaana at the University of Ottawa. The purpose of this study is to explore the implementation, impact, and use of using digital contact tracing during the COVID-19 pandemic from the perspective of hospital stakeholders.

To do this, we are interviewing a sample of healthcare administrators and healthcare workers to gather information on the perceptions and observations related to the digital contact tracing used at CHEO. We aim to provide a comprehensive description on the digital contact tracing tool's implementation and impact during the COVID-19 pandemic. Specifically, you will partake in one interview lasting approximately 30-60 minutes in length. The interviews will take place in-person (dependent on the pandemic situation) or through a secure videoconferencing platform of your choice (i.e., Zoom or Microsoft Teams). If in-person interviews are permitted, you may also request the interview to be conducted virtually should it be more convenient. You will be asked to provide information about the benefits, challenges, and the perceived effectiveness of using digital contact tracing during the COVID-19 pandemic from your point of view. There are no known risks associated with this study.

Your participation in this study will help to inform improvements in the quality of the digital contact tracing service used at CHEO. Your participation will also contribute benchmarking evidence on digital contact tracing in hospital settings. Be assured that your identity will remain confidential, and the results of the study will only be reported at the aggregate level. All data will be securely stored in encrypted files on a password-protected laptop. The data will be conserved for five years on a password-protected laptop.

If you have any questions regarding the ethical conduct of this study, you may contact the CHEO Research Ethics Board Tel.: 613-737-7600 ext. 3272.

We thank you for your precious collaboration,

Principal Investigator: Brynn O'Dwyer
Affiliation: MSc in Health Systems, Candidate
Telfer School of Management
Email Address:
Telephone number:

Supervisor: Dr. Mirou Jaana
Affiliation: Professor and MHA Program Director
Telfer School of Management
Email Address: jaana@telfer.uottawa.ca
Telephone number: 613-562-5800 x 3400

CHEO Principal Investigator: Dr. Chuck Hui
Division of Infectious Diseases, Immunology and Allergy
Email: chui@cheo.on.ca
Telephone number: 613-737-7600 ext. 2651

Version date: 30-Sep-2022

RESEARCH INSTITUTE
INSTITUT DE RECHERCHE

Informed Consent Form for Participation in a Research Study

Study Title: Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study

Principal Investigator: Dr. Charles Hui, Division of Infectious Disease, 613-737-7600 ext. 2651

INTRODUCTION

You are invited to participate in a study entitled 'Exploring Stakeholders Perspectives of Digital Contact Tracing in a Hospital Context: A Qualitative Study*'* that is being conducted by Dr. Hui, Dr. Mirou Jaana and Brynn O'Dwyer. Ms. O'Dwyer is required to conduct research as part of the requirements for the MSc in Health Systems degree and is being conducted under the supervision of Dr. Mirou Jaana. If you have any questions, you may contact Ms. O'Dwyer by phone or by e-mail. You may also contact her supervisor by phone 613-562-5800 x 3400 by e-mail (jaana@telfer.uottawa.ca).

You are invited to participate in this study because we are seeking hospital stakeholders' perspectives on the digital contact tracing used at Children's Hospital of Eastern Ontario (CHEO). This consent form provides you with information to help you make an informed choice. Please read this document carefully and ask any questions you may have. All your questions should be answered to your satisfaction before you decide whether to participate in this research study.

Taking part in this study is voluntary. You have the option to not participate at all or you may choose to leave the study at any time. There will be no impact on your employment if you decide not to participate in the research.

IS THERE A CONFLICT OF INTEREST?
There are no conflicts of interest to declare related to this study.

WHY IS THIS STUDY BEING DONE?

The purpose of this study is to explore the implementation, impact, and use of using digital contact tracing during the COVID-19 pandemic from the perspective of hospital stakeholders. To do this, we are interviewing a sample of healthcare administrators and healthcare workers to gather information on the perceptions and observations of the digital contact tracing used at CHEO. We aim to comprehensively describe the digital contact tracing tool's implementation and impact during the COVID-19 pandemic. Additionally, we aim to improve the quality of the digital contact tracing tool.

HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

It is anticipated that about 20 CHEO employees will participate in this study. This study should take 11 months to complete, with the results known in this timeframe.

WHAT WILL HAPPEN DURING THIS STUDY?

You will be asked to participate in 1 interview. During this interview, you will speak with or meet with Brynn O'Dwyer, a graduate student who is part of the research team. Interviews will be about 30-60 minutes in length and will take place in-person (dependent on the pandemic situation) or through a secure videoconferencing platform of your choice (i.e., Zoom or Microsoft Teams). If in-person interviews are permitted, you may also choose to participate virtually. You will be asked to provide information about the benefits and challenges, facilitators and barriers, and perceived effectiveness of the digital contact tracing tool used at CHEO during the COVID-19 pandemic.

To ensure the accuracy of the findings, you will also have to opportunity to review a draft of the results. This activity will last approximately 30-60 minutes. You may decline to partake in reviewing the draft of the results.

The information you provide is for research purposes only. You will be audio recorded during the interview for analysis purposes.

HOW LONG WILL PARTICIPANTS BE IN THE STUDY?

Your participation in this study will last approximately 30-60 minutes. You will only be required to participate in one interview. If you choose to review the draft results this will take an additional 30-60 minutes.

CAN PARTICIPANTS CHOOSE TO LEAVE THE STUDY?

You can choose to end your participation in this research (withdrawal) at any time without having to provide a reason. If you choose to withdraw from the study, please inform the research team about your decision.

You may withdraw your permission to use information that was collected about you for this study at any time by letting the research team know. If you decide to leave the study, you can ask that the information that was collected about you not be used for the study. Let the research team know if you choose this.

WHAT ARE THE RISKS OR HARMS OF PARTICIPATING IN THIS STUDY?

There are no known risks to you from participating in this study but taking part in this study You may take breaks throughout the interview if desired. You can refuse to answer questions or leave the interview at any time should you experience any discomfort.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

You may not receive direct benefits from participating in this study. We hope the information learned from this study will contribute knowledge that will help the organization facilitate improvements in the digital contact tracing tool. The results from this study will also include benchmarking evidence by contributing new insights on digital contact tracing use and its impact on maintaining infectious disease outbreaks in a high-risk hospital setting.

HOW WILL PARTICIPANT INFORMATION BE KEPT CONFIDENTIAL?
If you decide to participate in this study, the research team will only collect the information they need for this study.

Records identifying you at this centre will be kept confidential and, to the extent permitted by the applicable laws, will not be disclosed or made publicly available, except as described in this consent document.

Authorized representatives of the following organizations may look at your original (identifiable) records, to check that the information collected for the study is correct and follows proper laws and guidelines.

- The research ethics board who oversees the ethical conduct of this study
- This institution and affiliated sites, to oversee the conduct of research at this location

Information that is collected about you for the study (called study data) may also be sent to the organizations listed above. Your name, address, email, or other information that may directly identify you will not be used. The records received by these organizations may contain your participant code, and your occupation (role at the hospital).

During the interviews, participants will be encouraged to refrain from using names. If names or other identifying information is shared during the interview, it will not be included in the written records.

The use of virtual platforms, like any internet communication or storage and retention of information, involve privacy risks around access and disclosure of information. However, there are safeguards in place to reduce these risks, (e.g., account registration, meeting passwords, disposal of records or devices on which information is stored).

The audio recordings will be stored in a secure location and viewed only by members of the research team. The data collected will be stored for a period of 5 years, and then they will be destroyed.

The study results will only be reported at the group level. The information collected during this study is expected to be published or presented at academic conferences. We may use brief, direct quotes from the interview, but we will not identify you by name or any other personal information. If the results of this study are published, your identity will remain confidential. Even though the likelihood that someone may identify you from the study data is minimal, it can never be eliminated entirely.

WHAT IS THE COST TO PARTICIPANTS?

Participation in this study will not involve any additional costs to you.

ARE STUDY PARTICIPANTS PAID TO BE IN THIS STUDY?

You will not be paid for taking part in this study.

WHAT ARE THE RIGHTS OF PARTICIPANTS IN A RESEARCH STUDY?

You will be told, in a timely manner, about new information that may be relevant to your willingness to stay in this study. You have the right to be informed of the results of this study once the entire research is complete. If you would like to be informed of the results of this study, please indicate so at the end of the consent form.

Your rights to privacy are legally protected by federal and provincial laws that require safeguards to ensure that your privacy is respected.

By signing this form, you do not give up any of your legal rights against the researcher, or involved institutions for compensation, nor does this form relieve the researcher of their legal and professional responsibilities.

You will be given a copy of this signed and dated consent form prior to participating in this study

WHOM DO PARTICIPANTS CONTACT FOR QUESTIONS?

If you have questions about taking part in this study, or if you suffer a research-related injury, you can talk to the research team, or the person who is in charge of the study at this institution. That person is:

Dr. Charles Hui	613-737-7600 x 2651
Name	Telephone

If you have questions about your rights as a participant or about ethical issues related to this study, you can talk to someone who is not involved in the study at all. That person is: CHEO Research Ethics Board Tel.: 613-737-7600 ext. 3272

RESULTS

☐ I would like to be informed of the study results via email.
☐ I would not like to be informed of the study results.

SIGNATURES

By replying to this email, I attest that:

- All of my questions have been answered,
- I understand the information within this informed consent form,
- I understand that the interviews may be conducted using videoconferencing platforms (Zoom/Microsoft Teams), has privacy risks associated with its use,
- I agree that my participation in the interviews will be audio recorded for research purposes,
- I do not give up any of my legal rights by signing this consent form,
- I agree to take part in this study.

_____	_____	_____
Signature of Participant	PRINTED NAME	Date

_____	_____	_____
Signature of Person Conducting the Consent Discussion	PRINTED NAME & ROLE	Date

Appendix D: Data Structure

RE-AIM Dimension	Aggregate Dimensions	Themes	Categories	1st Level Codes
Reach	**Facilitators of Engagement**	Self-Awareness and Safety Practices	Values-Driven Initiative	• Personal accountability • Attitude on contact tracing • Awareness of exposure • Personal lives
		Usability and Familiarity	Technology-level Facilitators	• Ease of use • Convenient operations • Individual/organizational familiarity of platform • Frequent use
	Barriers to Engagement	Accessibility and Support	Technical Barriers	• Access and initiation of tool • Availability of support to navigate the tool • Usability of the tool
		Concerns of Risk-Assessment	Personal Impacts of Risk-Assessment	• Reluctance to complete based on fear of blame/mistrust in questioning • Financial implications • Privacy concerns
Effectiveness	**Perceived Benefits of Digital Contact Tracing**	Agile Response to COVID-19	Technology Usefulness	• Ease of data collection • Defined structure/standardization • Workforce optimization • Flexibility and adaptation to evolving guidelines • Quick guidance changes
		Timely and Broad Reach	Distribution of Tool	• Ability to be distributed among multiple users • Timely reach • Timeliness of communication/guidance
		Informed Decision Making	Multi-level Reporting and Insight	• Guiding decision making • Data usability and availability • Multi-level reporting • Decreased spread on patients, staff, community

	Challenges and Unintended Consequences	Staffing Impacts	Furloughing Staff	• Furloughed staff:
				  ○ Impact on patients
				  ○ Impact on unit

		Technology Limitations	Platform Challenges and Limitations	• Unintended for contact tracing • System performance • Nuances lost/accuracy of data • Communication gap • Determining exposure
	Effectiveness Indicators	Responsiveness and Engagement	Staff Engagement	• Staff response rate • Time to response • Staff satisfaction • Ability to be distributed among multiple users • Timely reach and follow up

		Infection Management	Nosocomial Outbreak	• COVID-19 detection and symptom monitoring • Rate of outbreak • Mitigation adherence • Accuracy of assessment • Staffing impacts
		Technical Operations	Technology Usability	• Efficient and transparent operations • Ease of use • Ability to report
Adoption	**Facilitators of Staff Adoption**	Safety-focused Culture	Engaging Communication Strategies	• Broadcasting information (hospital intranet) • Communication of work standards • Sick pay/incentivizing safety
		Personalized Guidance	Human-centered Technology	• Customization and personalization of direction/guidance • Trust and creditability of nurses involved
	Barriers of Staff Adoption	Misalignment with Frontline Practices	--	• Email habits among front-line staff • Difficulty to reach frontline staff by email
		Sustaining Participation	Low response rates	• Burden and stress of continuous reminders and COVID-related tasks • Overassessment • Clinical areas • Perceived significance, attention, and value to contact tracing • Evolving perspectives on COVID-19
Implementation	**Implementation Dynamics and Procedures**	Maintaining Compliance	Navigating Risk and compliance during COVID-19	• Government mandates and compliance • Organizational responsibilities • Nature of clinical areas
		Fostering Trust and Confidence	Establishing Trust Among Staff	• Staff anxiety, concern, and fear of COVID-19 exposure • Building trust among staff
		Maximizing Efficiency	Leveraging Technology for Efficiency	• Limitations of traditional contact tracing • Availability of resources • Time sensitive nature of contact tracing • Standardization • Large scale disease management
		Innovative Leadership	Implementation Champions	• Clear vision • Novelty/innovative approach • Awareness of technology
		Collaboration	Partnership	• Platform considerations • Involvement of affiliated intuitions • Collective efforts • Formation of response team
	Implementation Challenges	Digital Disconnect	Desire for Human-Centered Communication	• Desire for direct validation and reassurance from nurses • Staff initial frustration

				• Reduced direct interaction
		Resource Management and Partnership	Technical Complexity and Resource Requirements	• Skills required • Complex technical infrastructure • Dependent on affiliated institutions • Interpersonal conflict
Maintenance	**Adaptions and Modifications**	Iterative Improvements	Necessary Changes	• Refinements: user feedback, questions (content, structure, format) • Modifications to reflect evolving guidance • Mechanisms of tool delivery
	Navigating Future Sustainability	Transferability beyond COVID-19	Suitability for Other Infectious Diseases	• Resurrect to address needs • Adaptability and suitability for other infectious diseases
Areas of Improvement	**Enhanced Usability and Access**	--	Clear Functionality	• Simplified questions • Remove redundancy • Reconfiguration • Access to tool
	Prioritizing Training and Education	--	Preparing Staff for Change	• Earlier communication • Clear expectations • Sufficient knowledge and training

	Expansion and Integration	--	--	• Alternative platforms
				• Alternative methods of delivery
				• Expansion of tool
				  ○ Public health
				  ○ Additional reporting
				  ○ Hospital systems

Appendix E: Summary of Perceived Effectiveness Indicators

Key Area	Indicators and Description
1. Responsiveness and Engagement	1.1 ***Efficiency in Reaching Target Audience*:** Evaluating if a DCT approach has the capacity to consistently reach the target audience. 1.2 ***Timeliness of Delivery***: Examining the speed at which the technology is deployed to its target audience. 1.3 ***DCT vs Traditional Contact Tracing Approaches:*** Analyzing the timeline of case investigations when employing DCT approaches compared to traditional contact tracing. 1.4 ***Staff Satisfaction with DCT:*** Measuring staff satisfaction on the utilization/output of DCT. 1.5 ***Staff Confidence in DCT:*** Measuring staff members' confidence in the hospital's safety mitigations that were facilitated by DCT.
2. Infection Indicators	2.1 ***Symptom Management:*** Investigating if DCT enables staff to monitor symptoms more effectively, and subsequently leading to reduction in transmission. 2.2 ***Outbreak Prevention:*** Determining the extent to which DCT contributes to preventing outbreaks and reducing nosocomial transmission. 2.3 ***Risk Mitigations:*** Evaluating if DCT helps to enhance or decrease safety mitigations. 2.4 ***Accuracy of Risk-Assessment:*** Evaluating the reliability and accuracy of DCT for identifying high-risk individuals. Includes assessing whether additional must be solicited from the target audience to facilitate case investigations. 2.5 ***Patient Outcomes***: Evaluating if the DCT had any associated impacts on patients.
3. Technical Operations	3.1 ***Flexibility and Adaptability:*** Evaluating if the DCT can be adapted to make changes in response to evolving needs. 3.2 ***User-Friendliness:*** Assessing if the technology is user-friendly for its intended audience.

3.3 ***Transparency:*** Evaluating if the outcomes of the DCT are clear and transparent for the users.

3.4 ***Data Storage and Reporting:*** Assessing the technologies capabilities to store and share data.