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Digital Transformation and Infection Control Strategies

Mariana Nabais Domingues

Mestrado em Gestão de Serviços de Saúde

Orientador:
MD, PhD, MLaw, FIAHSI, Professor Henrique Martins

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ISCTE-IUL

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ABSTRACT

Healthcare-associated infections (HAIs) are a leading cause of mortality and morbidity worldwide, placing a burden on society and hospitalized patients. Despite the interventions implemented in most healthcare facilities, these are still insufficient to counteract the rise in prevalence of this type of infections. Within the context of infection control, Digital transformation (DT) has the potential to reduce costs, improve effectiveness and overall quality of care. Digital and innovative approaches can help reduce the prevalence and severity of HAIs. However, the implementation of these type of technologies and methodologies in healthcare is not yet generalized, and particularly in infection control strategies', digital-first is not yet common practice.

This study aims to understand the perception and knowledge of DT in infection control strategies in Portuguese hospitals. A survey was designed based on literature about digital support and interventions in infection control, resulting in 34 full responses. Results indicate that knowledge about DT is limited and the use of digital technologies in the context of infection control is low. However, Infection Control Committees also reported an interest in the implementation of these technologies, both to improve data collection methods and to increase quality of care. Lack of funding, technical knowledge and shortage of human resources were cited as some of the main obstacles for DT.

Overall, results highlight the importance of understanding, promoting, and validating DT to build confidence, further promote and reinforce the establishment of such processes under Infection Control Committees activities.

Keywords: Healthcare; Hospitals; Healthcare Associated Infections; Digital Transformation; Digital Technologies; Information and communication technologies.

Classification JEL: I10: Health; I15 Health and Economic Development.

RESUMO

Infeções associadas aos cuidados de saúde (IACS) são uma das principais causas de mortalidade e morbilidade no mundo, constituindo um fardo para a sociedade e doentes. Apesar das intervenções implementadas na maioria das unidades de saúde, estas são ainda insuficientes para contrariar o aumento da prevalência destas infeções. No contexto do controlo de infeções, a transformação digital (TD) tem o potencial de reduzir custos e melhorar a eficácia e qualidade dos cuidados. As abordagens digitais podem reduzir a prevalência e a gravidade das IACS. No entanto, a implementação deste tipo de tecnologias nestas organizações ainda não é uma prática comum.

Este estudo foca-se na perceção e conhecimento da TD nas estratégias de controlo de infeção nos hospitais portugueses. Um questionário elaborado com base em literatura sobre este tema, resultou em 34 respostas completas. Os resultados indicam que o conhecimento sobre TD é limitado, assim como a utilização de tecnologias digitais no contexto do controlo de infeção. No entanto, as Comissões de Controlo de Infeção demonstraram interesse na implementação destas tecnologias, tanto para melhorar os métodos de recolha de dados como para aumentar a qualidade dos cuidados. A falta de financiamento, de conhecimento técnico e de recursos humanos foram citados como alguns dos principais obstáculos à TD.

Estes resultados destacam a importância de compreender, promover e validar a TD para criar confiança, promover e reforçar a criação desses processos no âmbito das atividades das comissões de controlo da infeção.

Palavras-chave: Cuidados de saúde; Hospitais; Infeções associadas aos cuidados de saúde; Transformação digital; Tecnologias digitais; Tecnologias de informação e comunicação.

Classificação JEL: I10: Saúde; I15: Saúde e Desenvolvimento Económico

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GLOSSARY OF ACRONYMS

AD – Automated disinfection;

aHP – Aerolized Hydrogen Peroxide;

AI – Artificial Intelligence;

Apps – Applications;

CAUTI – Catheter-associated Urinary Tract infection;

CLABSI – Central Line-associated Bloodstream Infection;

DT – Digital Transformation;

EHHM – Electronic Hand Hygiene Monitoring;

EHR – Electronic Health Records;

GCL-PPCIRA – Local Coordination Groups from Program for the Prevention and Control of Infections and Antimicrobial Resistance;

GCR-PPCIRA – Regional Coordination Groups from Program for the Prevention and Control of Infections and Antimicrobial Resistance;

GNB – *gram-negative bacilli;*

HAI – Health care-associated infection;

HCP – Healthcare Professional;

HH – Hand Hygiene;

HPV – Hydrogen Peroxide Vapor;

HR – Health Region;

ICC – Infection Control Committees;

ICT – Information and communication technologies;

ICUs – Intensive Care Units;

IPC – Infection Prevention and Control;

MDRO – Multidrug-Resistant Organisms;

MRSA – *Methicillin-resistant Staphylococcus aureus;*

PPCIRA – Program for the Prevention and Control of Infections and Antimicrobial Resistance;

PX-UV – Pulsed-xenon Ultraviolet C;

RQ – Research Questions;

RTL – Real Time Location;

SSI – Surgical Site Infections;

U.S. – United States of America;

UTI – Urinary Tract Infection;

UV-C – Ultraviolet C;

VAP – Ventilator-associated pneumonia;

WHO – Words Health Organization;

1) INTRODUCTION

1.1) Context

Healthcare-associated infections (HAIs) are a global public health problem. They are common causes of illness and mortality among hospitalized patients (Parmeggiani et al., 2010; Pina et al., 2010; Scardoni et al., 2020; Song et al., 2019). The World Health Organization (WHO) estimates that HAIs are the most frequently occurring adverse event in any healthcare system regardless of existing resources (Stewart et al., 2021), being currently one of the most significant causes of death worldwide (Pina et al., 2010; Song et al., 2019). According to available estimates, 55 to 70% of HAIs are preventable (Bearman et al., 2019; Haque et al., 2020).

Healthcare-associated infections afflicts millions of people annually around the world, causing death to 1 in every 10 infected individuals (WHO, 2022a). In acute-care hospitals of high-income countries, out of 100 patients, 7 are predicted to acquire at least one HAI; this number increases to 15 in low-and middle-income countries (WHO, 2022a). In healthcare settings for more vulnerable populations, the economic and social burden of HAIs are particularly severe. Due to the clinical severity and the greater usage of invasive procedures, intensive care units (ICUs) have a higher incidence of HAIs. Additionally, the prevalence rates of these infections may be higher in some geographical areas with few resources and insufficient infection control methods (WHO, 2022).

Even the most advanced nations and developed health systems cannot claim to be immune to HAIs (WHO, 2022). In Europe, annually, around 3.2 million people are affected by HAIs (European Center for Disease Control and Prevention, 2013; Verberk et al., 2022), a higher burden than all other reported infectious diseases (Scardoni et al., 2020).

The Direção Geral de Saúde, Ministry of Health (Portugal) showed that the incidence rate of HAIs in Portuguese hospitals had decreased between 2015 and 2020. However, HAIs remain a very relevant issue in Portugal, with the most recent prevalence study made in 2017 indicating an overall HAIs rate of 7.8%. There was a reduction in the rate of HAIs (7.8 versus 10.5%) and antimicrobial consumption (38.8 versus 45.5%) compared to the survey carried out in 2012 (Programa de Prevenção e Controlo de Infeções e de Resistências aos Antimicrobianos, 2022).

With the COVID-19 pandemic resulting in drastic spikes in hospitalizations and an increase in mortality (Weiner-Lastinger et al., 2022), it is important to understand the potential impact of this pandemic on HAIs prevention and surveillance (Rong et al., 2023). This is especially relevant given how little information there was at the beginning of the pandemic about how hospitalizations caused by this virus would affect the incidence of HAIs (Rong et al., 2023).

Data from the National Healthcare Safety Network shown, in U.S. hospitals, a significant increase in some HAI types coincident with the period of high COVID-19 hospitalizations (Centers for Disease Control and Prevention, 2022; Weiner-Lastinger et al., 2022). However, the important improvements in hand hygiene (HH) revealed a strong decline in infections provoked by *Clostridioides difficile*. Continuous transformations to healthcare organizations practices, longer hospitalization stays, additional co-morbidities and higher need for utilization of devices are all motives that could possibly contribute to a generally increase in infections caused like devices (Centers for Disease Control and Prevention, 2022; Weiner-Lastinger et al., 2022). However, this data does not cut across all hospitals globally. For example, a study carried out by hospitals in China during the same period revealed a considerably decreased of HAIs prevalence since the outbreak of this virus, especially in respiratory infections, probably due to the reinforced surveillance and implementation of additional control measures at the hospital (Rong et al., 2023).

Healthcare-associated infections not only have a negative impact on patients' outcomes, but a significant economic burden as well (Alhumaid et al., 2021; Scardoni et al., 2020; Tchouaket Nguemeleu et al., 2020). Monetary valuations of the economic cost of HAIs are important for decision making and should be estimated accurately (Graves et al., 2010).

In order to ensure safe and effective patient care across all levels of care, compliance to preventative and control measures for these infections is essential (Centers for Disease Control and preventative, 2022). Despite the existence of specific interventions to prevent HAIs in healthcare facilities (WHO, 2016a, 2019) and (Centers for Disease Control and Prevention, 2022), these revealed insufficient as the rate of HAIs keeps growing. However, it is crucial to concentrate on currently available technologies that provide positive outcomes in this area (Ali et al., 2021).

The past two decades have been characterized by a fast dissemination and a quick implementation of information and communication technologies (ICTs) in several domains of public health (Iyamu et al., 2021), with many health organizations and healthcare systems adopting them in their various functional areas (Appleby et al., 2021). Developments in ICTs, especially regarding digital transformation (DT), have the potential to improve the control of infections (Ali et al., 2021).

The increased use and subsequent reliance on digital technologies ushers in a slew of major changes in businesses, industries, and society as a whole. As such, the concept of DT was created to further implement and apply these technologies (Van Veldhoven & Vanthienen, 2022).

A considerable number of DT-related studies have emerged as a result of the previously described changes, but a clear grasp of DT is still to be achieved. This lack of understanding persists due to the diversity of the research stream and the lack of a strong foundation of a common understanding of this crucial concept (Gong & Ribiere, 2021).

Healthcare has been one of the main fields for DT. A topic of increasing relevance for both scholars, healthcare professionals (HCPs) and managers (Brommeyer et al., 2023; Brommeyer & Liang, 2022; Dohan et al., 2020). Healthcare ICT is an ever-evolving field, continuously changing the way in which healthcare is provided (Kraus et al., 2021). Digital transformation in healthcare incorporates many aspects from DT in other fields (Kraus et al., 2021), allowing for the implementation of new technologies assisting in the delivery of safety and high-quality care and in optimizing efficiency (Haggerty, 2017). These technologies also improve the speed, reliability, and reach of infectious diseases (like HAIs) control measures (Ali et al., 2021), while also enhancing the capacity for diagnose and manage these infections (Ali et al., 2021; Fitzpatrick et al., 2020). The continuous progress in digital technologies and the increasing digitalization of health data have allowed the automation of HAIs surveillance, as a new foundation for effective HAIs prevention and control (Adlassnig et al., 2014; Behnke et al., 2021; Scardoni et al., 2020).

Despite this, there is still a critical need for trustworthy technologies that can direct patient management by foretelling the likelihood of HAIs and their unfavorable outcomes, easing the strain of these infection on healthcare systems (Barchitta et al., 2021). Reliable digital technologies have the ability to dramatically improve infection control practices, increasing the efficiency and effectiveness of infection prevention and management and, most importantly, increasing patient safety (Ali et al., 2021; Huang et al., 2021).

There are several digital technologies that are commonly used on healthcare environment in infection prevention and control, and they can be grouped mainly into six different categories:

- Automated disinfection (AD) systems, to prevent the human error associated to convention cleaning and disinfection (Otter et al., 2013).
- Electronic Health Records (EHR) for detection and surveillance of HAIs on a better way then manual surveillance (de Bruin et al., 2016).
- Applications (Apps) for Mobile Devices, as they can support diffusion and understanding of evidence to decrease HAIs (Schnall & Iribarren, 2015).
- Electronic Hand Hygiene Monitoring (EHHM) systems, with HH being considered one of the most relevant measures to prevent HAIs (Jeanes et al., 2020).
- Real Time Location (RTL) systems, by utilizing wireless technology to monitor patients, HCPs or equipment (Dufour et al., 2017).

- Artificial Intelligence (AI) based systems, by supporting the development of HAI monitoring algorithms and systems (Scardoni et al., 2020).

This represents a potential positive relationship between successful DT and an improved management of the risk of infections or a better management of HAIs once these are established. Acknowledging that a successful DT relies on people's perspectives and their understanding of it (Verhoef et al., 2021), studying these can help better implement these novel methodologies and technologies, ultimately making hospitals safer institutions for patients.

1.2) Research Aim and Questions

The aim of this study is to understand how digital transformation and digital technologies are being considered in infection control strategies of Portuguese hospitals, more specifically by their Infection Control Committees (ICCs). The focus of this investigation is Portuguese Hospitals located in the 7 Health Regions (HR, corresponding to the portuguese term *regiões de saúde*): HR Norte; HR Centro; HR Alentejo; HR Lisboa e Vale do Tejo; HR Algarve; HR Madeira; HR Açores.

There is a relationship between DT and a better management of the risk of infections, their occurrence and its management (Ali et al., 2021). Is recognized that a successful DT hinges on people's perspectives and their knowledge of it (Ismail et al., 2017). Therefore, understanding ICC knowledge, perspectives, and attitudes towards the use of digital technologies can inform polices of digital and innovation introduction in infection control strategies.

Research Questions and their context

Throughout this research, four key research questions (RQ) have been explored: ***RQ1) What evidence exists on the use of digital technologies in infection control strategies?***

Healthcare-associated infections are a severe problem in the healthcare services as they are common causes of illness and mortality among hospitalized patients. Therefore, it is crucial to understand how DT and digital tools can have a role on this matter. Consequently, it will be necessary to get involved with the topic of the study, by understand which type of scientific evidence exists on literature about the possible relation between the use of digital technologies and infection control strategies associated with healthcare.

RQ2) What is the impact of the use of digital technologies in infection control?

It is necessary to understand the impact that digital technologies have around infection control strategies, specially to acknowledge if it is negative or positive for the healthcare organizations.

RQ3) Does digital transformation of infection control strategies have a financial impact?

Healthcare-associated infections are not only a significant cause of mortality and morbidity but are also associated with a financial burden that affects both patients and healthcare institutions worldwide (Tchouaket Nguemeleu et al., 2020). Thus, it is of crucial importance to understand the role of HAIs in financial terms and trying to understand whether DT can have an influence on this matter.

RQ4) What is the perception and experience of Portuguese Hospitals related to digital technologies of infection control?

To answer this question will be accomplished a formal questionnaire and sent to selected Portuguese Hospitals by email. This email will contain important information about the questionnaire, a brief resume about the topic of the questionnaires: what evidence exists about the use of digital technologies on infection control strategies on Portuguese Hospitals ICCs, the propose of the questionnaire and the questionnaire itself.

1.3) Dissertation Structure

The structure of this thesis is as follows: chapter one will provide a concise contextualization of the issue and its significance. The research questions, aim, and objectives are also presented. Chapter two establishes a theoretical foundation upon which to base the study; the background for this thesis is given based on solid literature review. Chapter three explains the methodology used, particularly the questionnaire's structure and main steps undertaken. In chapter four results are presented. Chapter five analyzes these results. Discussion of results in light of the research questions advanced constitutes chapter six . To finish, limitations of this study are listed, and suggestions for future work and considerations are advanced, in chapter seven, eight and ten, respectively.

2) BACKGROUND

2.1) Healthcare Associated Infections

In hospital settings these infections can be called nosocomial or hospital infections, but the official and general name is HAIs. These are an infection occurring in a patient during the process of care in a hospital or primary health care facility which was not present or incubating at the time of admission (WHO, 2010). In order to be considered a HAI, the infection cannot be present and not in incubation when the patient is hospitalized in the health care unit and appear 48 hours or more after admission, or within 30 days after having received health care (Haque et al., 2018). This definition also includes occupational infections that affect HCPs and visitors of the patients (World Health Organization, 2016).

Healthcare-associated infections can be classified into different types based on the source or site of the infection. According to the European Centre for Disease Prevention and Control (ECDC), the most frequently reported types of HAIs are respiratory tract infections, surgical site infections (SSIs), urinary tract infections (UTIs), bloodstream infections and gastro-intestinal infections (European Centre for Disease Prevention and Control, 2023; Haque et al., 2018). The equipment used in medical treatments, such as ventilators or catheters is sometimes linked to infections. These include ventilator-associated pneumonia (VAP), central line-associated bloodstream infections (CLABSIs) and catheter-associated urinary tract infections (CAUTIs) (European Centre for Disease Prevention and Control, 2023; Haque et al., 2018; Umscheid et al., 2011). A summary of these can be seen in Table 1.

An infection that develops up to 30 days after surgery is classified as a SSI (Owens & Stoessel, 2008), being associated with mortality and morbidity rates and heavy demands on the resources available for healthcare, with a prevalence as high as 20% (Owens & Stoessel, 2008).

Any infection affecting the urethra, bladder, ureters, or kidney is referred to as a UTIs, being the most common type of HAIs (Centers for Disease Control and Prevention, 2015), and globally affects about 150 million individuals annually (Werneburg, 2022). About 75% of UTIs developed in a hospital are linked to the presence of an inserted urinary catheter. CAUTIs are UTIs occurring in an individual whose urinary bladder is catheterized or has been catheterized within the past 48 hours, being the most common HAI and cause of secondary bloodstream infections (Werneburg, 2022).

Ventilator-associated pneumonia is a term used to describe pneumonia that develops in a patient who has been on mechanical ventilation for more than 48 hours. VAP accounts for 7% to 32% of all HAIs (Lefebvre et al., 2022). In addition to mortality, the economic burden of this HAI include longer ICU stays with incremental costs, between 5 and 20 thousand dollars per diagnosis (Koenig & Truwit, 2006).

Central line-associated bloodstream infections are a laboratory-confirmed bloodstream infection not related to another site that develops within 48 hours of central line placement which can result in extended hospital stays, rising healthcare expenses, and a higher mortality rate (Centers for Disease Control and Prevention, 2011). According to the available estimates, in the U.S., 250,000 bloodstream infections happen each year, and the majority of them are caused by intravascular devices. At roughly $46,000 per incidence, CLABSIs are among the HAIs with the biggest economic burden (Centers for Disease Control and Prevention, 2011; Haddadin et al., 2022).

Table 1: Overview of some of the principal types of HAIs, regarding a brief description. Source: the author.

Principal Types of HAIs	Description
Respiratory tract infections	Every infectious disease of the upper or lower respiratory tract (National Institute for Health and Clinical Excellence, 2008).
Ventilator-associated Pneumonia (VAP)	Pneumonia that develops in a patient who has been on mechanical ventilation for more than 48 hours; accounting for 7% to 32% of all HAIs (Lefebvre et al., 2022).
Surgical Site Infections (SSIs)	Infection that develops up to 30 days after surgery, with a prevalence as high as 20% (Owens & Stoessel, 2008).
Urinary Tract Infections (UTI)	Any infection affecting the urethra, bladder, ureters, or kidney, being the most common type of HAIs (Centers for Disease Control and Prevention, 2015).
Catheter-Associated Urinary Tract Infections (CAUTIs)	Urinary tract infection that occurs in an individual whose urinary bladder is catheterized or has been catheterized within the past 48 hours, being the most common HAI and cause of secondary bloodstream infections (Werneburg, 2022).
Bloodstream Infections	Infectious diseases defined by the presence of viable bacterial or fungal microorganisms in the bloodstream (Viscoli, 2016).
Central Line-associated Bloodstream Infections (CLABSIs)	Laboratory-confirmed bloodstream infection not related to another site that develops within 48 hours of central line placement (Centers for Disease Control and Prevention, 2011).
Gastro-intestinal Infections	Common global health problem that mostly often affect the stomach or intestines (Burd & Hinrichs, 2016), with *Clostridium difficile* being responsible for almost half these infections (European Centre for Disease Prevention and Control, 2023).

About 12 to 17 microorganisms cause 80%–87% of HAIs and among these pathogens, from 16 to 20% include multidrug-resistant strains (Haque et al., 2018). The most prevalent ones include Clostridioides (*Clostridium*) *difficile*, *methicillin-resistant*

Staphylococcus aureus (MRSA), *vancomycin-resistant enterococci* (VRE), *gram-negative bacilli* (GNB), and norovirus (Donskey, 2013), existing mandatory and specific monitoring programmes for the prevention and control of these four microorganisms (Tchouaket Nguemeleu et al., 2020).

Heathcare-associated infections can lead to low quality of life, or even reduce life expectancy of the infected person, as well as incur considerable costs in the long run (Alhumaid et al., 2021). The impact of HAIs not only imply long hospital stays as also possible long-term disability, increased resistance of microorganisms to antimicrobials, a massive additional financial burden, high costs for patients and their families, and excess, the ultimate possible death of patients (Tchouaket Nguemeleu et al., 2020; World Health Organization. Patient Safety, 2009). However public attention to HAIs typically only occurs during outbreaks (Haque et al., 2018).

Heathcare-associated infections are inevitable and place a tremendous burden on society and hospitalized patients by increasing morbidity and mortality (Graves et al., 2010; Lotfinejad et al., 2021; Pittet et al., 2005). Globally millions of people are affected every year with HAIs, even though between 55% to 70% are totally preventable (Alhumaid et al., 2021). Despite that, no country or health system can claim to be free of this problem (World Health Organization, 2016). In every healthcare organization and health system, the global burden is impossible to quantify because it is difficult to gather reliable data (World Health Organization. Patient Safety, 2009). Overall estimates show that more than 1,4 million patients worldwide in developed and developing countries are affected at any time (World Health Organization. Patient Safety, 2009).

Recent studies developed in Europe show that HAIs affect millions of patients annually with up to 80,000 affected in Europe on any given day (Cassini et al., 2016), with a prevalence rate ranging between to 4.6% from 9.3% (World Health Organization. Patient Safety, 2009). Between 3,1 and 4,6 million patients in acute care hospitals in the EU, Iceland, Norway, and the UK acquire a HAI per year, causing more than 90,000 deaths annually (Suetens et al., 2018). Presently, between 5% to 10% of patients declared to acute care hospitals acquire at least one HAI and over the last decades the incidence has increased in Europe and U.S. (Parmeggiani et al., 2010). Annually, HAIs in acute care hospitals in Europe result in an additional 25 million days spent in hospitals, costing between €13 and €24 billion (WHO, 2009).

According to estimates, the prevalence of HAIs at any given time is between 3 and 12% in high-income countries and 5 and 19% in low-and middle-income countries. However, given the underreporting of HAIs from many countries, this estimate may only be a small portion of the true prevalence (Lotfinejad et al., 2021).

Due of their more serious clinical circumstances, patients in ICUs have a greater incidence of HAIs (Barchitta et al., 2021; Haque et al., 2018), with the possibility to impact up to 30% of intensive care patients (World Health Organization, 2022). According to WHO, one in four patients hospitalized in ICUs has a bigger risk of developing a HAI, and this value may be up to twice as high when referring to low-income countries (Organization, 2002). Every year, around 500 thousand people are diagnosed with HAIs only in ICUs (Haque et al., 2018). In developed countries, HAIs prevalence lies between 5% to 15% of hospitalized patients and can affect from 9% to 37% of those admitted to ICUs (WHO, 2009).

Although, trying to compare this burden with other communicable disease is an ongoing challenge given the need for good quality data on the incidence of the infections and the involved comorbidities (Cassini et al., 2016). The overall direct cost of HAIs to hospitals in the U.S. ranges from USD 28 billion to 45 billion, when in Europe those are estimated at USD 12 billion per year (Cassini et al., 2016). WHO, conscious of the problems that HAIs give both to patients and health system, has recurrently focused on issues related to infection control and prevention, being declared that this topic is crucial for settings and organizations committed to make the safer care delivery for all (World Health Organization. Patient Safety, 2009).

Having active infection prevention and control (IPC) strategies is a proven effective way to protect patients, HPCs, and visitors to healthcare facilities. A faulty IPC strategy causes harm and can kill, being impossible to achieve quality health care delivery (Storr et al., 2017; World Health Organization, 2023). Based on statistics from 166 nations worldwide for 2021–2022, one in ten of those countries do not have any national IPC programs or operational plans. Only 38% of nations, the vast majority of which are high-income nations, reported having an IPC program completely implemented at the national as well as at the level of healthcare facilities countrywide (World Health Organization, 2023).

To achieve a strong health system, it is crucial to work continuously with the aim to integrate an IPC strategy at all the levels. A good implementation of these strategies is key to translate guidelines into practices. This depends on people effective leadership, relaying on multimodal/multidisciplinary strategies; monitoring approaches; patient centered methods; integrated clinical processes; innovative and locally adapted; tailored to specific cultures and resources (Allegranzi, 2018). There is a wealth of evidence about the importance of this matter and how it can reduce HAIs among patients, with a recent study from WHO reveling that well-established IPC programmes could reduce HAIs by up to 70% (World Health Organization, 2022). Better results are achieved when IPC is supported by management and political support, combined with quality medical services and a patient safety culture (World Health Organization, 2016). With this digitalization of healthcare creates novel opportunities for automating HAI control and surveillance processes to varying degrees (Murphy et al., 2020). Current HAI control and surveillance systems are focused on manual medical records review, vulnerable to misclassification and expensive (Scardoni & Odone, 2019). These new technologies and methodologies have the power to increase the capacity to both detect and respond to emergent infectious diseases by being capable to provide automatic and real-time mapping, create different sources of data, and facilitating the discovery of pathogens, while at the same time saving resources (Ali et al., 2021).

2.2) Infection Control Committees

In Portugal, HAIs were recognized as a problem for the first time in 1930 by the Directorate-General for Health (Fernando & Bastos, 2010) and then in 1979 by the Directorate-General for Hospitals, through Information Circular No. 6/79, of 9/2/79. Infection control was firstly recommended for Hospitals to all health units by Informative Circular No. 8/86 of 25/03/86. Since then, several ground-breaking initiatives have been implemented to reduce risk and manage infection in hospitals, including the Order of the Director-General of Health of October 23, 1996, which established ICC in public and private health facilities that are a part of the national health service. Afterwards, the National Infection Control Program was created (Direção Geral de Saúde, 2007).

With the evolution and emergence of these issues in Portugal, and with the aim of mitigating them, Health Programs dedicated specifically to these topics have emerged. Order no. 2902/2013, of February 22, created the Program for the Prevention and Control of Infections and Antimicrobial Resistance (PPCIRA), thus merging the previous national programs, namely the PPCIRA Regional Coordination Groups (GCR-PPCIRA) in the RHA and the Local Coordination Groups (GCL-PPCIRA) in health units, hospitals, primary health care and the integrated long-term care network (Paiva et al., 2021).

Given the need to strengthen the improvement of numerous health indicators within the scope of this Program in response to the effects of the COVID-19 disease pandemic, it was justified to update PPCIRA's mission and updated its structure adapted to the expanding and emerging challenges affecting the entire National Health Service. The mission of PPCIRA is to prevent and control HAIs, promote the prescription, and appropriate consumption of antimicrobials and reduce the emergence and transmission of antimicrobial resistance, through quality improvement, educational and behavioral interventions (Paiva et al., 2021). The objectives of this program are to reduce HAIs rate, promote the correct use of antimicrobials and reducing the rate of antimicrobial-resistant microorganisms, having been defined as a priority health program, within the scope of the National Health Plan, by Order no. 6401/2016, of May 16, in its current wording. The fundamental activities of PPCIRA include:

a) Epidemiological surveillance of HAIs, consumption, and resistance to antimicrobials.
b) Promoting adherence to and compliance with basic infection control precautions and precautions based on the route of transmission.
c) Promotion and implementation of HAI prevention bundles.
d) Promotion and development of antimicrobial prescription support programs.
e) Production of Standards and Guidelines and educational training activities for professionals.
f) Formulation and development of behavioral training methodologies, including commented feedback of data and facilitation of quality improvement interventions.
g) Promotion and implementation of HAI prevention intervention measures.

PPCIRA's current structure is governed by a director appointed by Order no. 3335/2020 and four PPCIRA Director's Assistants appointed by Order no. 9806/2020

Currently, regarding Order no. 10901/2022, of September 8th, GCL-PPCIRA exist in all National Health Service hospitals and have their responsibilities well defined. These include:

a) Promote and supervise local infection prevention and control practices and the use of antimicrobials.
b) Ensure mandatory compliance with epidemiological surveillance programs for HAIs, antimicrobial consumption and antimicrobial resistance.
c) Ensure compliance with basic infection control precautions and precautions based on transmission routes.
d) Promote local isolation practices to contain multi-resistant and/or epidemiologically significant agents.
e) Ensure the return of information on epidemiological surveillance of infection, antimicrobial consumption and antimicrobial resistance to clinical units.
f) Ensure compliance with national PPCIRA and DGS standards and guidelines and collaborate with the Regional PPCIRA Unit and the national PPCIRA directorate in the Program's activities.
g) Collaborate in the process of reporting notifiable diseases.
h) Promote the investigation of possible outbreaks, namely by carrying out epidemiological.
i) Surveys and collaborate in audits.

j) Promote the acquisition of knowledge in this area, through research and quality.
k) Quality improvement.
l) Service director and the head nurse of each clinical service as their main interlocutors, contracting objectives and targets with each service.
m) Integrate its activities into the annual activity plan and report of the Regional PPCIRA Unit and the national PPCIRA board.

GCL-PPCIRA is considered an organic unit of the respective institution, with a medical director and a nurse manager, or with management functions, appointed by the board of directors, on the proposal of the clinical director and the nursing director, respectively, both personalities with recognized competence and increased capacity in this area. These groups operate according to specific rules. The director and the nurse manager, or those with management functions, must have their entire schedule dedicated to this group; the nature of the members of this group must be multidisciplinary, including doctors, nurses, pharmacists and other health technicians linked to the area of intervention, namely a member with skills in quality science and implementation science; among other mandatory criteria. Also, GCL-PPCIRA interacts with the epidemiology service, unit or center and with the quality and safety unit, service or commission, ideally in an integration. Its director must be a member of the quality and safety committee, as well as the pharmacy and therapeutics committee of the respective hospital.

Within the scope of this work, for ease, and better understanding for all parties (especially when non-Portuguese audience), from now on, the GCL-PPCIRA will be referred as ICCs.

2.2) Digital Transformation

A theme that has been frequently mentioned in the literature in recent years is “digital health”, being a complicated and multi-sided phenomenon that cannot be easily reduced to a few common characteristics (Belliger & Krieger, 2018). Digital health can be defined as “a cultural transformation of how disruptive technologies that offer digital and objective data accessible to both caregivers and patients leads to an equivalent level doctor-patient relationship with shared decision-making and the democratization of care”, introducing transformations in delivering care and performing medicine (Meskó et al., 2017).

New technology transforms the management and provision of healthcare (Schreiber et al., 2018). With technological innovations becoming more inseparable from healthcare and as healthcare systems worldwide becoming financially unsustainable, a paradigm shift is imminent (Meskó et al., 2017). While many industries are experimenting

DT, recent analyses have demonstrated that successful industries' improved competitive posture is not just based on the technologies they use, but also—and maybe more importantly—on the strategies they employ (Ismail et al., 2017). Health service managers need to have the necessary skills and knowledge to enable data-driven, strategic, operational decision-making and the capacity to lead and manage digital health transformation. In this time of systemic transformation, managers of these institutions must address the issues posed by the rise in digital health literacy and be skilled in planning and managing the digital tools and technology throughout this evolving landscape (Stoumpos et al., 2023).

Digital technologies have been widely adopted in many health organizations in the attempt to improve the quality of service to the patient and increase productivity and efficiency in healthcare provision (Marques & Ferreira, 2020). Health technologies have improved continuously ever since the primary stages of medicine. Increasing knowledge and diagnostic, preventive and control, treatment and rehabilitation potentials have modified the content of health care systems. Successively, health systems have also developed into complex units with different roles and responsibilities for patients, healthcare providers, payers, and regulators (Ricciardi et al., 2019). Digital transformation of health services is expectant to show a substantial impact on current healthcare and healthcare organizations, expecting to have a further fundamental impact on health care and health care delivery in the future, being this as a critical and significant process, which must be given due attention by all interested parts (Ricciardi et al., 2019). With digital transformation referring to "a fundamental change process enabled by digital technologies with the aim of introducing improvements and radical innovations in an entity to create value for stakeholders, strategically promoting its key resources and capabilities" (Gong & Ribiere, 2021) it is straightaway acknowledged that DT on healthcare is a complex and multifaceted issue (Ricciardi et al., 2019).

Recent developments in ICT, especially in digital technologies, can considerably improve important functions related with public health, like infection diseases, and their control and prevention (Ali et al., 2021).

2.3) Digital Technologies

Multiple IT systems have overtaken many hospitals (Behnke et al., 2021), and their industry is receiving interest primarily because digital technologies can offer practical solutions to the HAIs problem. As so, these types of infections take advantage from the use of these tools by improving their diagnostic techniques, increasing understanding of the disease, and slowing the spread of infection (Tilahun et al., 2021).

Automated Disinfection systems, Electronic Health Records, Applications for mobile devices, Electronic Hand Hygiene Monitoring systems, Real Time Location systems and AI based systems are different categories of digital technologies that offer creative answers for front-line defense, quicker detection, and infectious risk management to lower rates of morbidity and mortality and the effects of those rates (Ferrara et al., 2022).

Table 2 lists the different types and sub-types of digital technologies used in infection control discussed in the sections below, including a brief description and real-life examples.

2.3.1) Automated Disinfection Systems

There has been growing focus on the need of good cleaning and disinfection as the function of contaminated surfaces in the transmission of HAIs is increasingly acknowledged (Otter et al., 2019). Given that the research establishing correlations between infection risk and contaminated surfaces has just recently started to gather, this has undoubtedly helped justify the work and resources expended (Dancer, 2014).

The cleaning procedure itself is a topic of discussion regarding frequency, techniques, equipment, criteria for surface cleanliness, benchmarks, and monitoring. Conventional cleaning and disinfection techniques depend on a human operator to properly choose, prepare, and distribute a suitable agent to all target surfaces for the required contact time (Otter et al., 2013). The evolution of these established practices requires challenging changes in human behavior. To eliminate human mistake, automated technologies have been widely used in other facets of healthcare (Otter et al., 2013, 2019). Utilizing new AD systems offer a different strategy to achieve that goal.

One of the biggest benefits after implementing an AD system is the improved terminal disinfection of clinical areas after infected or colonized patients have been discharged to reduce environmental-borne transmission (Otter et al., 2013). AD systems are also used to clean medical equipment in a special facility, operating rooms, and remove environmental infections disturbed during building work as part of disaster preparedness planning. This result in a significant reduction of contamination by HAIs. The viability and efficacy of AD systems for disinfecting these items should be prioritized for assessment due to the potential for mobile medical equipment to become contaminated as well as the difficulty in effectively disinfecting them (Otter et al., 2013).

Currently, a variety of AD systems are utilized in healthcare settings. The more commonly used in this domain are ultraviolet-C light (UV-C), aerosolized hydrogen peroxide (aHP) and hydrogen peroxide vapor (HPV). Another class of AD systems has appeared quite recently, based on pulsed-xenon UV (PX-UV) (Otter et al., 2013, 2019).

All these four categories of AD systems are distinctive so is needed to discuss deeply in which scenarios the different systems apply, depending on their intended application (Otter et al., 2019).

2.3.1.1) Ultraviolet-C Light Systems

Pathogens from contaminated surfaces might not be eliminated only by manual cleaning and disinfection. AD devices that use UV-C radiation are being promoted more as a complement to traditional decontamination techniques (Astrid et al., 2021), with an increase in its use in a variety of locations including airports, retail centers and especially healthcare facilities (Astrid et al., 2021) .

UV-C light is a method of preventing infection that uses light wavelengths to kill bacteria and inactivate viruses (Ramos et al., 2020), while being simple to use, doesn't need air vents or doors to be sealed, and has a quick cycle time (Otter et al., 2013). Research suggests that UV-C irradiation-based disinfection methods are effective to lower the environmental microbial burden and lowering the risk of contracting a HAI, with reduce workload and time consumed (Astrid et al., 2021).

A 2016 study conducted by Centers for Disease Control and Prevention concluded that the incidence of HAI-causing microorganisms decreased by up to 35% after adding antimicrobial UV-C emitting devices to standard cleaning procedures (Martinello et al., 2018). Automated UV-C emitting devices have been shown to reduce the bioburden of significant infections in healthcare facilities rooms, with reductions of 30% to 70% in *C. diff.* documented, with MRSA and other infections have also had comparable outcomes (Martinello et al., 2018).

2.3.1.2) Aerosolized Hydrogen Peroxide Systems

Aerosolized Hydrogen Peroxide (aHP) systems deliver a pressure-generated aerosol. The most common systems used in healthcare use a solution called “dry-list hydrogen peroxide” or “aHP”, with 5-6% H_2O_2 (hydrogen peroxyde) and less than 50 ppm silver ions (Otter et al., 2013, 2019). It has been demonstrated that aerosolized H_2O_2 devices can lessen *C. difficile* and MRSA infection on surfaces of healthcare facilities. However, there is few medical evidence that aHP systems can completely eliminate infections (Otter et al., 2013).

Is common to compare on literature aHP systems with HVP systems and UV-C systems. Aerosolized H_2O_2 systems are easier to operate and more affordable, when compared with the other types of technologies. However, the capacity of aHP systems is more limited, with a reduced capacity to decontaminate areas bigger than single rooms, being needed multiple generators for that effect (Otter et al., 2013).

2.3.1.3) Hydrogen Peroxide Vapor Systems

Hydrogen peroxide in their vaporized form is used as surface disinfection (Totaro et al., 2020). To achieve uniform distribution throughout a space, Hydrogen Peroxide Vapor (HPV) systems disperse a heat-generated vapor of 30% to 35% (w/w) aqueous H_2O_2 through a high-velocity air stream (Otter et al., 2013; Weber et al., 2016). Is reported that these types of technologies have an increased level of efficacy and short cycle times (Weber et al., 2016).

HPV systems have been utilized to disinfect individual spaces as well as bays with many beds or even entire units (Otter et al., 2013) with their level of effective being well documented on research (Weber et al., 2016). The ability of HPV systems to inactivate viruses and bacteria introduced onto test surfaces has been shown in numerous studies. Systems that use H_2O_2 vapor can inactivate mycobacteria, nonenveloped viruses, large quantities of bacterial spores and can lower the number of multidrug resistant organisms (MDROs) that contaminate surfaces in healthcare facilities rooms (Weber et al., 2016).

Since HPV requires two units (a generator and an aeration unit) for a single room, it is more complex than UV-C and aHP systems. Using HPV systems requires more staff training than using UV systems (Otter et al., 2013).

2.3.1.4) Pulsed-xenon Ultra-violet Systems

Pulsed-xenon Ultraviolet (PX-UV) technology can be used adjected to cleaning regimens on healthcare facilities, without relying on a professional. Full-spectrum UV light has been proven to significantly increase environmental cleanliness, even entirely eradicating MDROs from some high-touch surfaces (Vianna et al., 2016). PX-UV systems are placed at several room locations and work with a relatively short cycle time, emitting a broad UV spectrum in short pulses (Otter et al., 2019). Most notably, healthcare facilities that use this type of systems have considerably reduced the risks of infection brought on by environmentally mediated transmission channels. Referring to MRSA and *C. Difficile* infections, when using PX-UV their rates dropped 53% and 56%, respectively (Vianna et al., 2016). About MDROs within the acute care setting, PX-UV have the power to reduce their HAIs rates by 20% (Catalanotti et al., 2016).

Though this type of technology can be relevant in ICUs, where patients use in-dwelling medical devices more frequently and have higher patient acuity, research also suggest that PX-UV could be extended to acute care, non-ICU inpatient situations where scientific evidence is currently missing (Vianna et al., 2016).

2.3.2) Electronic Health Records

Intensive surveillance that identifies variations in medical indications that call for frequent, repetitive, and thorough bedside examination on a patient-by-patient basis is one of the most effective methods for reducing HAIs in healthcare facilities (Lo et al., 2014). Over the past years, electronic systems for the medical purpose have become widespread for the identification and monitoring of HAIs, with potential to lessen the workload associated with reporting infectious illness data, as well as increase its completeness and timeliness (Leach et al., 2021). With electronic methods being quicker, involving fewer human resources, and are not prone to inter-rater variability as is the case with manual surveillance, electronic monitoring is thought to be preferable to traditional surveillance (de Bruin et al., 2016). The growing availability of heath data made possible to deliver highly detailed and precise information about the epidemiologic connections between hospital patients and staff (Cusumano-Towner et al., 2013). The accessibility of data from many sources could benefit electronic HAI surveillance system by cutting costs and saving time and enabling real-time analysis and response (Scardoni et al., 2020).

Electronic Health Records (EHRs) can be defined as patient care records that a computer is capable of processing (Gliklich et al., 2019). EHR now contain an increasing amount of sophisticated HAI monitoring data due to the increased deployment of their systems in recent years. Not only is the storage, access, and transfer of medical records an unheralded benefit of EHRs, but also the analysis of the data that is contained in those records. However, some of the more sophisticated EHR systems can notify clinicians of patients who may have risky prescription combinations or drug allergies or even prompt medical personnel to run specific tests or monitor side effects or symptoms. As a result, it is possible to efficiently gather data on HAI surveillance across the entire hospital (Lo et al., 2014).

2.3.3) Applications for Mobile Devices

Mobile wireless technologies have a major role in our lives, being especially pertinent because of how simple, widespread, and accepted they are (Bentvelsen et al., 2021; WHO, 2018). Mobile devices have therefore been acknowledged as potentially beneficial instruments to support healthcare, with a relevant increased in their use on this domain (Bentvelsen et al., 2021; Schnall & Iribarren, 2015).

WHO defines mobile health (mHealth) as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices.” (WHO, 2023). mHealth apps can run in mobile devices, like smartphones or tablets, and can be utilized to offer HCPs with scientific proof in their clinical contexts (Schnall & Iribarren, 2015). According to the 2015 WHO worldwide survey, 83% of nations were operating at least one national mHealth initiative (WHO, 2016b). This recent practice has been demonstrated to expand access to health information, services, and skills, improve the quality and coverage of care, and encourage healthy behavioral changes that delay the onset of both acute and chronic diseases (WHO, 2018).

The rising use of mHealth apps presents an opportunity to employ apps to prevent and identify HAIs in clinical settings (Bentvelsen et al., 2021). This is especially important for HAIs, because can aid in the broadcast and application of data to lessen and finally eradicate these infections (Schnall & Iribarren, 2015). When the apps are developed carefully and based on scientific evidence are very useful both for HCPs as for their patients, because they can contribute to reduce HAIs rates, offering quick and easy access to multiple guidelines, encouraging HH monitoring, outlining methods to prevent infections, or giving detailed directions on how a healthcare facility should be laid out can all help to reduce HAIs (Schnall & Iribarren, 2015).

2.3.4) Electronic Hand Hygiene Monitoring Systems

It has been established how crucial hands are in the spread of infectious pathogens (Knepper et al., 2020). The association between a strong HH and a decrease in HAIs (as well as decreasing the spread of germs) (Guest et al., 2019; Knepper et al., 2020) has been shown in numerous contexts for more than one century (Ellingson et al., 2014), with HH always being considered the most significant and inexpensive infection prevention measure in all healthcare facilities (Barbon et al., 2022; Ellingson et al., 2014; Jeanes et al., 2020; Knudsen et al., 2021). It is estimated that from 20% to 30% of HAIs could be prevented only by better HH compliance (Haque et al., 2020).

Prevention of HAIs through consistent HH monitoring and feedback is suggested by the WHO (Meng et al., 2019). Epidemiological data shows that hand-mediated transmission in one of the most impacting factors in acquiring and spreading infections in healthcare organizations, especially hospitals (Barbon et al., 2022; Guest et al., 2019; Tseng et al., 2022). Although, even at facilities with plenty of resources, only about 40% of people follow the advised HH procedures, despite the tremendous relevance that this assumes (Ellingson et al., 2014). In low-income countries this percentage drops to less than 20% (Lotfinejad et al., 2021).

Currently, trained observers' direct observation is the gold standard for HH monitoring, although it has a lot of flaws. In general, direct observation can only record a relatively small portion of all HH chances, and it is subject to inter-auditor differences and the Hawthorne effect bias. Therefore, data collected by direct observation cannot be regarded as accurate (K. R. Cawthorne & Cooke, 2021; Knepper et al., 2020).

Over the past few years, technological advancements have been made to try to solve the problems related to direct observations of HH and consequently to track and enhance to their compliance (K. R. Cawthorne & Cooke, 2021). EHHM systems are one of these technologies, existing evidence that shows they lead to better HH (K. R. Cawthorne & Cooke, 2021). These are useful in determining the best practices for HH improvement among different professional groups and document variations in HAIs rates related to those improvements (Knudsen et al., 2021). EHHM systems will also collect a bigger amount of HH data, helping on the robustness of the monitoring (K. R. Cawthorne & Cooke, 2021). One of the strategies to increase the efficacy of these systems is to provide custom and non-punitive feedback to HCPs, individual or in group (K. R. Cawthorne & Cooke, 2021) (Knudsen et al., 2021).

2.3.5) Real Time Location Systems

Real Time Location (RTL) systems are technologies that can identify and track the location of assets and/or individuals in real or near-real-time (Bazo et al., 2021; Kamel Boulos & Berry, 2012), and so are able to model the spread of HAIs (Surian et al., 2019). These low-cost technologies use specialized fixed receivers or readers that gather wireless signals from ID badges or tags attached to objects of interest and/or individuals, to find the tagged entities (Kamel Boulos & Berry, 2012).

The utilization of an appropriate RTL system has the potential to be very beneficial for healthcare facilities, especially hospitals (Kamel Boulos & Berry, 2012), enhancing their efficiency and automation (Ramos et al., 2020). These technologies can be utilized to fast locate HCPs or patients in large organizations (Kamel Boulos & Berry, 2012); to track assets to HCPs and/or patients; link location data with other data (such EHR) and optimize workflow by stealthily mining data (Bazo et al., 2021). RTL systems can also be used as a strategy to analyze HCPs adherence to HH (Bazo et al., 2021; Dufour et al., 2017; Knepper et al., 2020).

2.3.6) Artificial Intelligence and Machine Learning Based Systems

Artificial Intelligence can be simply defined by being a computer system that execute tasks that often need human intelligence, generally relating pattern recognition that is followed by some action or decision (Fitzpatrick et al., 2020). However, Machine Learning is a subdomain of AI where the computer utilizes algorithms to get knowledge from datasets used of before with the goal to make predictions about new data, instead of performing a set of programmes rules (Fitzpatrick et al., 2020). Several AI based algorithms are available for use in healthcare (Barchitta et al., 2021; dos Santos et al., 2021; Fitzpatrick et al., 2020).

With manual surveillance being labor exhaustive, expensive and with lacks standardization increases (Scardoni et al., 2020), the potential of AI in clinical medicine is enormous (Fitzpatrick et al., 2020). AI systems can identify trends in the data as healthcare IT systems produce enormous amounts of data, speeding up the detection of outbreaks and supplying richer datasets for further analysis (Scardoni et al., 2020). AI can model solutions by replicating the behavior of many types of agents inside a complex system, promote change by gathering data and creating analytics, and can support the case for system change by highlighting the cost of action (Fitzpatrick et al., 2020).

The development of HAI surveillance systems targeted at comprehending HAIs risk factors, improving patient risk stratification, identifying transmission channels, and prompt or real-time detection may be supported by AI (Scardoni et al., 2020). Specifically, applications of AI are used to predict the risk of *Clostridium difficile* infection on people (Fitzpatrick et al., 2020). In addition, AI algorithms may more easily adapt to the dynamic nature of healthcare instead of traditional surveillance models, allowing the infection control and clinical team to be informed when the risk of CD infection increases during their inpatient stay. Also, AI data mining of routine microbiology test findings could be used in the clinical microbiology laboratory to identify and forecast clusters/outbreaks of MDROs colonization and/or infection occurrences (Fitzpatrick et al., 2020).

One significant problem for public health is identifying patients in ICUs who are more likely to contract HAIs. The use of AI may enhance patient risk assessment and result in more precise IPC measures, being suggested that the use of these type of digital technologies is a valuable tool to anticipate specific adverse outcomes and for risk stratification in intensive care units (Barchitta et al., 2021).

Table 2: Summary of the different types of digital technologies applicable in IPC. Source: the author.

Type	Subtype	Description and Applications in IPC	Technologies Example's
Automated Disinfection Systems	Ultraviolet-C Light Systems	Method that uses light wavelengths to kill bacteria and inactivate viruses (Ramos et al., 2020). UV-C irradiation-based disinfection methods are effective to lower the environmental microbial burden and lowering the risk of contracting a HAI, with reduce workload and time consumed (Astrid et al., 2021).	- Tru-D SmartUVC - THOR UVC Sterilization Robot - ARTZ 2.0 Mobile UVC Solutions - Optimum-UV Enlight - Hyper Light Disinfection Robot - Steriliz R-D Rapid Disinfector - The TORCH - Sanuvox - Surfacice Helios System - PATHOGON UV Disinfection System - UVD Robot - UVDI-Biodecon
	Aerosolized H2O$_2$ Systems	Systems that deliver a pressure-generated aerosol that can lessen some HAIs on surfaces of healthcare facilities.	- Glosair 400 - Carfil Quality Products
	H_2O_2 Vapour Systems	Systems disperse H_2O_2 vapor, with an increased level of efficacy and short cycle times (Weber et al., 2016), with the ability to inactivate viruses and bacteria introduced onto test surfaces has been shown in literature.	- Steris VHP Systems - Bioquell BQ-50 - Synexis DHP Products - Oxy'pharm Products
	PX-UV Systems	Systems that a broad UV spectrum in short pulses (Otter et al., 2019), reducing the risks of infection brought on by environmentally mediated transmission channels.	- Xenex Disinfection Services - Violet Defense
Electronic Health Records	Defined as patient care records that a computer is capable of processing, being able to identify and monitor HAIs, with potential to lessen the workload associated with reporting infectious illness data, as well as increase its completeness and timeliness (Leach et al., 2021).		- Monitor ICU System - MONI Suport - PICS Software - HEPIC

Apps for Mobile Devices	The rising use of smartphones and mHealth apps presents an opportunity to employ apps to prevent and identify HAIs in clinical settings (Bentvelsen et al., 2021). This is especially important for HAIs, because apps for mobile devices can aid in the broadcast and application of data to lessen and finally eradicate these infections (Schnall & Iribarren, 2015).	- Ecolab EnCompass - Guideline Central - Health Facility Guidelines Pro - Infection Control Pocketbook - Infection Prevention Manual - Catheter Pro - RCH Clinical Guidelines - ESVS Clinical Guidelines - EVS High Touch Test - EVS Patient Protector - MicroGuide - PIVM LCI_richtlijen - The Chief Complaint
Electronic HH Monitoring Systems	Systems that lead to better HH (K. R. Cawthorne & Cooke, 2021), being useful in determining the best practices for HH improvement (Knudsen et al., 2021). EHHM systems collect a bigger amount of HH data, helping on the robustness of the monitoring of HAIs (K. R. Cawthorne & Cooke, 2021).	- Biovigil - DebMed Electronic Hand Hygiene Compliance System - Droid Audio Visual Educator - MediHandTrace
Real Time Location Systems	Systems that can identify and track the location of assets and/or individuals in real or near-real-time (Kamel Boulos & Berry, 2012), and so are able to model the spread of HAIs (Surian et al., 2019). An appropriate utilization of these systems can be very beneficial for hospitals (Kamel Boulos & Berry, 2012), enhancing their efficiency and automation (Ramos et al., 2020).	- Products from CenTrak - Products from Secutitas Technology - Products from Zebra - Products from Sonitor
AI Based Systems	AI technologies may assist in the creation of HAI monitoring systems aimed at understanding HAI risk factors, enhancing patient risk classification, identifying transmission routes, and quick or real-time detection (Scardoni et al., 2020).	- Microsoft Power BI - Google Dashboard - Fireflies - Tableau - REDCap

3) METODOLOGY

A mixed method approach, that combine qualitative and quantitative research is becoming more common in healthcare management studies (Castleberry & Nolen, 2018), such was the methodology adopted in this study.

Qualitative research is a less structured approach that gathers information with the main goal of learning more about a phenomenon from the perspectives of those who have experienced it firsthand, while also appreciating the value of participants' distinctive points of view that can only be fully understood in the context of their experience and worldview. This allows a deep description of a certain theme, understanding of concepts, different opinions, or experiences (Castleberry & Nolen, 2018). On the other hand, with the aid of numerical expressions, quantitative approaches investigate the influences of conditions (an independent variable) on a result (a dependent variable) (Lakshman et al., 2000). Quantitative research is statistical and structured. This approach can find patterns, make predictions, and test possible relationships.

In this study, literature review and thematic identification and further discussion represents qualitative efforts undertaken, these were the basis for creating a survey tool – questionnaire - to be used with ICC from Portuguese Hospitals as target population, to obtain data for quantitative analysis which was latter discussed in light of themes previously identified.

3.1) Research Method

In order to obtain a better understanding of the contextual environment and the particularities of the object of study will be conducted a literature review. This deep research will allow the elaboration of a dense and complete questionnaire, that will lead the study to his final state.

Therefore, for data collection, the second section of this study was developed by succeeding the following steps: (1) Elaboration of a questionnaire around the topic "Digital Transformation in Infection Control Strategies"; (2) In order to familiarize the participants with the topic addressed by the questionnaire and to facilitate the understanding of the questions, preparation of a summary of the topic covered by the questionnaire; (3) Writing of a well-structured e-mail to send to the sample of the study, including important information about the questionnaire, a summary about the topic and the questionnaire itself.

3.2) Sampling Technique and Target Population

A non-probabilistic convenience sample design was chosen as the sampling method (Stratton, 2021; Taherdoost, 2016).

The target population of the present work are ICCs of Portuguese Hospitals, belonging to the seven health regions (HR) of Portugal. A search into Portuguese hospitals online information made it possible to determine the target ones for this study. 84 hospitals were identified, with 30 in the HR Norte; 16 in the HR Centro; 5 in the HR Alentejo; 22 in the HR Lisboa; e Vale do Tejo; 3 in the HR Algarve; 4 in the HR Açores and 4 in the HR Madeira. Both public and private hospital were considered.

Data was collected though internet from each of the hospitals selected. Namely data captured include district and county they belong to; whether they are National Health Service hospitals; name of the hospital; site link; general contact email; general phone number; if exists some reference to the ICC (under this or other similar name); link to the ICC page; direct contacts available for ICC (email or phone contact); name of the ICC Coordinator; ICC Constitution; available contact details of the coordinator/some member of the ICC (email or phone contact).

The hospitals that did not have any online indication about the contact to their ICC were left to a second phase. This was conducted using the phone contacts that hospitals provided on their website. A short phone call was made, where a small presentation of the researcher was followed by the subject of the study and it and was explained they were being contacted, asking if it would be possible to transfer the call to the ICC of their hospital. After phone transfer, a presentation of the researcher of the study and the explanation of why they were being contacted, in order to request an email contact either from the GCL-PCIRA itself or from a member of it, so that it would be easier to contact them.

3.3) Data Collection

3.3.1) Questionnaire development and distribution

It is important to understand the degree of penetration of digital transformation and digital technologies in the polices of infection control strategies in the ICCs of Portuguese hospitals. To this end, a detailed questionnaire was developed, based on findings from literature review (Appendix D).

The questionnaire was first developed in English and then translated to Portuguese, as this is the main language of the participants of the study.

The questionnaire was validated by one respondent of a Portuguese hospital who answered the pilot questionnaire. After clarifying some questions, the final version was sent to the target hospitals. The questionnaire was created on Google Forms, between March and May of 2023. The final version was distributed via an email with introduction texts and a link to Google Forms on June 1st. Questionnaire was online from 1st June to July 19th.

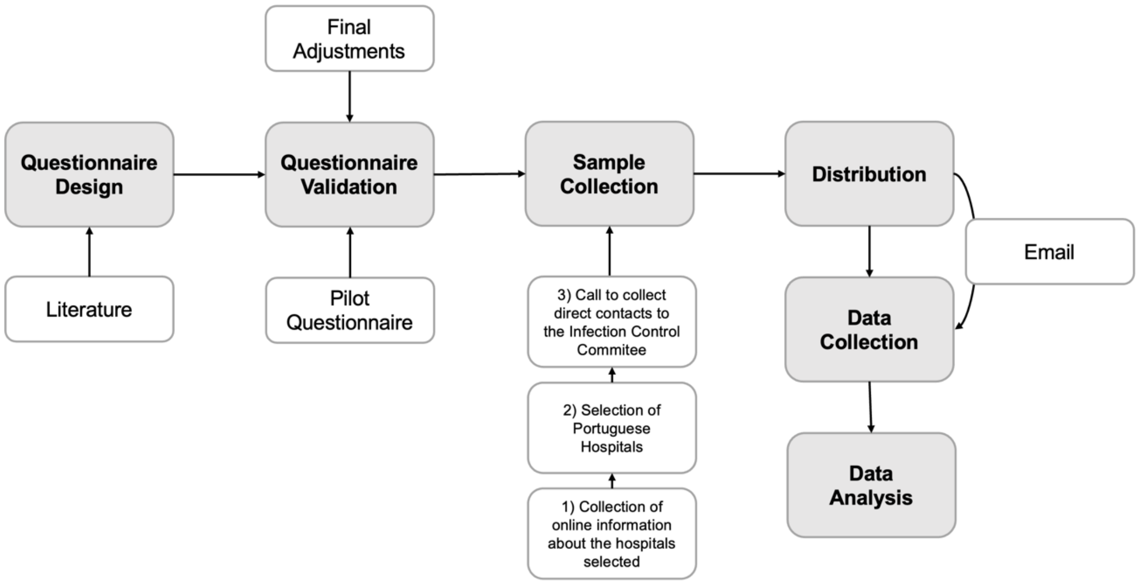

Figure 1: Methodology process. Source: the author.

The standard email sent to the 84 target hospitals and to members of ICCs, as well as the attachment sent in one of which emails can be found in Appendixes A, B and C, respectively.

The questionnaire structure was induced five main sections: (1) Hospital characterization; (2) Productivity tools used by ICCs; (3) Digital Technologies used in Infection Control; (4) Digital Transformation associated with Infection Control Strategies; (5) Perception and Attitude towards Digital Transformation.

The first section is focused on obtaining basic information about the healthcare facility itself, like their geographic localization, dimension and type of property and financing.

The second section aims to understand the utilization level of productivity tools on the ICC, through four questions containing examples of that specific tools, with the possibility for the participants to enumerate more examples of their knowledge and asses how they consider their own expertise on these tools throughout a Likert scale from 1 (very insufficient) to 5 (very sufficient).

The third section contemplate questions about specific technologies applied on the infection control strategies. These are divided in subsection where are discussed the different categories of digital technologies. Witch of these subsections includes examples of digital technologies accompanied by illustrative examples and a website with commercial information of the illustrative product. Participants are asked about how familiar they are with the digital technology presented, what is their use/intention to use it, and are also given the possibility to refer other examples of technologies for each of the respective sections.

The fourth section aims to understand the level of knowledge that participants have about digital transformation and how they rate the use of digital technologies and digital transformation in the hospital/ICCs where they practice functions for prevention and control of HAIs.

The fifth and final section of the questionnaire explores questions about participant'' opinions, analyzing what they consider about the relevance, challenges, and opportunities of digital technologies in healthcare settings.

3.3.2) Statistical analysis and technological instruments

Descriptive statistics were utilized to describe the sample in the five main assessment sections after data collection. Microsoft Excel (version 16.74) and Statistical Packages for the Social Sciences (SPSS) (version 23) were the selected programmes to analyze the results.

Moreover, to answer RQ4 12 different Chi-Square tests were executed under a confidence interval of 95%. These testes are one of the most helpful statistics for testing hypotheses with nominal variables by analyzing the possible associations between them (Franke et al., 2012; McHugh, 2012). The following variables were considered to perform reliable statistical tests, as shown in Appendix E.

4) RESULTS

In total, 38 responses were collected from 84 contacted hospitals (response rate of 45,2%) but finally a sample of 34 was used due to critical missing information in 4 responses (n=34).

4.1) Hospital characterization

As described in Figure 2, the largest number of responses obtained corresponded to hospitals belonging to Health Region (HR) Lisboa e Vale do Tejo (35,3%) (Q1). Only one response was obtained from a hospital belonging to HR Alentejo, Algarve and Madeira, corresponding to 2.9%, respectively. All regions represented in the sample.

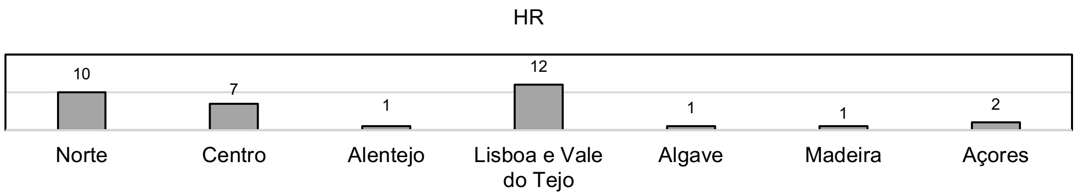

Figure 2: Answer distribution to Q1: To which HR does the hospital where you work belongs to?

In terms of the number of hospitals beds (Q2), half of them have a total number greater than 500 (50%), as present in Figure 3. All size typologies are represented in the sample.

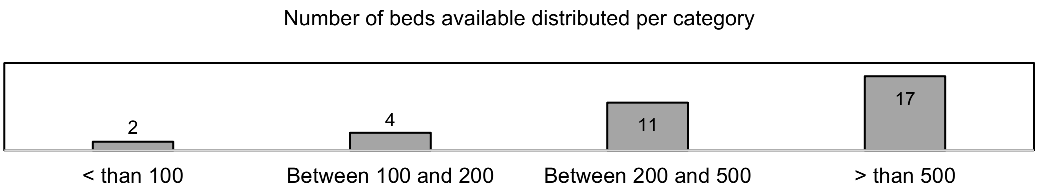

Figure 3: Answer distribution to Q2: What is the total number of beds available at the Hospital where you work (regardless of the type of healthcare)?

Only one hospital was private, in contrast with the remain that were public (Q3). One third of the hospitals were university hospital (32,4%) (Q4).

Nineteen hospitals (56%) claimed not to have any accreditation/certification (Q5). Within the 15 accredited/certified hospitals (Q6), 6 of them claimed to be accredited by CHKS; 5 claimed to be a Joint Commission International Accredited Organization; 3 presented the ACSA accreditation model.

4.2) Productivity tools used in ICCs

Twenty-three productivity tools which can be used by ICCs were presented and the degree of familiarity with them was asked (Q7). Results revealed that the level of familiarity with this type of tool is relatively high. The minimum number of tools with which hospitals felt minimally familiar was 8 and the maximum was 23. On average, hospitals felt minimally familiar with 13 of the presented tools.

When the sample was asked about other examples of productivity tools, the following were listed (Q8): Hepic; Doodle; Zotero; Mendeley; Google Forms; Microsoft Access; Prezi; Mentimeter, Meliora BI Hospitalar; Clinidata (Maxdata) and sClínico Hospitalar.

Regarding the generic degree of use of productivity tools by the ICC (Q9), more than 50% of the sample revealed that they considered their knowledge sufficient. Only one hospital considered its knowledge as fairly insufficient and very good (Figure 4).

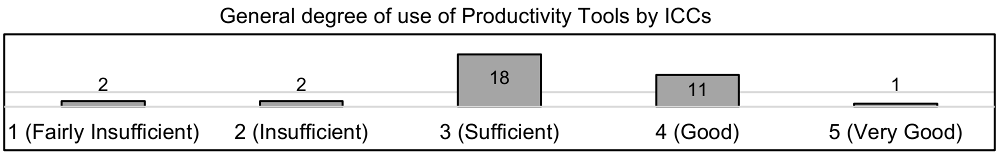

Figure 4: Answer distribution to Q9: How would you rate the general level of productivity tool usage by the ICC of the hospital where you work?

Considering Portuguese Hospitals ICCs, the sample considered that the ones that more uses productivity tools (Q10) were Centro Hospitalar Universitário do Porto (mentioned 8 times); followed by Centro Hospitalar Universitário de Coimbra, Centro Hospitalar de Tâmega e Sousa and Grupo Luz Saúde (both mentioned twice).

4.3) Digital Technologies used in Infection Control

4.3.1) Automated Disinfection Systems

4.3.1.1) Automated Disinfection Systems based on UV-C Light

When confronted with a specific technology (Tru-D SMartUVC) (Q11), as described in Figure 5, 11 hospitals (35,3%) reported that they have no relation to it; whereas more than the majority of the sample reported that they had already seen it perform its functions (55,9%) or even used it (8,8%).

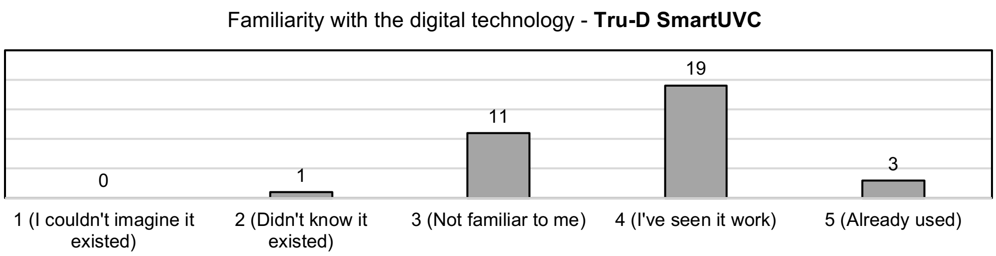

Figure 5: Answer distribution to Q11: How familiar are you with the digital technology presented in the video? (Tru-D SmartUVC)

When asked about the use/intention to use technologies of the same type (Q12), the results in Figure 6 demonstrated that 10 hospitals (29.4%) are making plans to implement the use of some technology of this type, while 5 (14.7%) already use it. Eight hospitals indicated that are not interested in the technology and do not intend to use it, while 7 hospitals (20.6%) do not use it but consider it interesting to use it in the future.

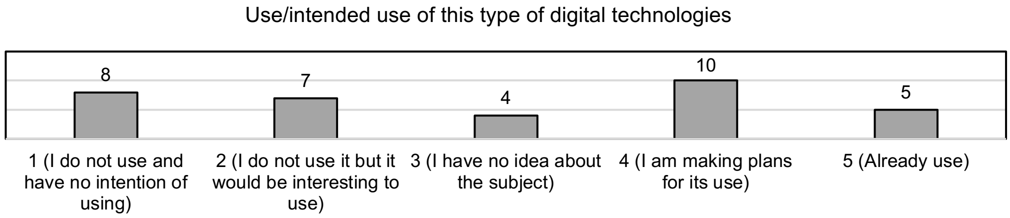

Figure 6: Answer distribution to Q12: In the hospital where you work, what is the use/intention of using this type of digital technology?

Other digital technologies of the same category were listed to assess whether the hospitals recognized them (Q13). Only a minority of the sample (20.6%) recognized other technologies.

Furthermore, it was given the opportunity for the sample to mention other technologies with the same objective that had not yet been mentioned (Q14). Two technologies were reported: UVD Robot by two hospitals and UVDI-Biodecon by one hospital.

4.3.1.2) Automated Disinfection Systems based on HP (H_2O_2) vapor

Regarding Steris VHP systems (Q15), as shown in Figure 7, the majority of responses showed that it is well known by the sample, with 32.4% having seen it in use and 35.3% having used it. Only 2 hospitals (5.9%) reported not knowing that this technology existed, while the remaining nine (26.8%) stated that it was not familiar to them.

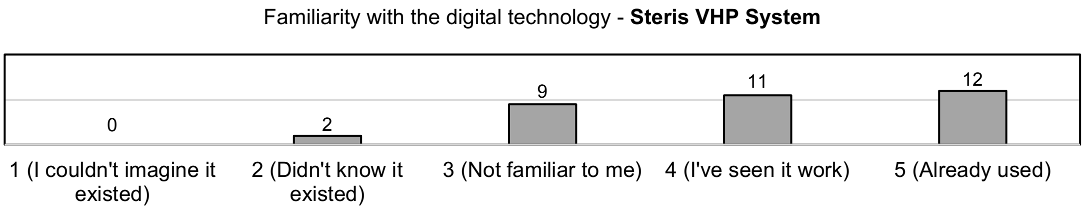

Figure 7: Answer distribution to Q15: How familiar are you with the digital technology presented in the video? (Steris VHP systems)?

When asked about the use or intention to use this type of technology (Q16), the results were positive, as can be seen on Figure 8. Thirteen hospitals (38,2%) reported having already used this type of technology, and 12 (35,3%) shown interest in using it in the future. Only a minority of 2 hospitals (5,9%) state that they do not use it or show intention to do so.

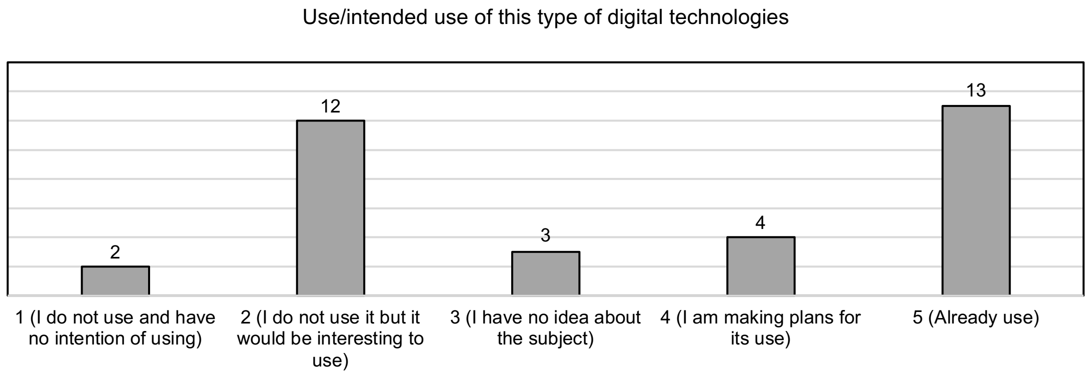

Figure 8: Answer distribution to Q16: In the hospital where you work, what is the use/intention of using this type of digital technology?

Moreover, other digital technologies on the same category were listed to assess whether the hospitals recognized them (Q17). Eleven hospitals (32,4%) recognized Bioquell BQ-50 from the listed technologies. Besides, in Q18, the sample had the opportunity to mention other technologies that had not yet been mentioned, with Nocosospray – Oxy'pharm being referred by 4 hospitals.

4.3.1.3) Automated Disinfection systems based on HP (H_2O_2) aerosol

Considering the Glosair 400 technology (Q19), most hospitals (27) found that they had no relationship with it, highlighting the 13 hospitals that stated that it was not familiar to them. These results are shown in Figure 9.

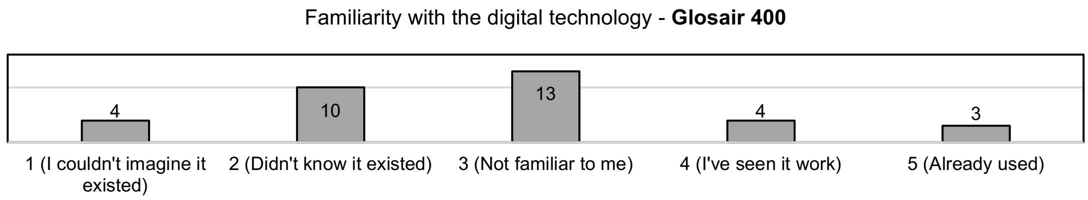

Figure 9: Answer distribution to Q19 How familiar are you with the digital technology presented in the video? (Glosair 400)?

When asked about the use or intention to use such technologies (Q20) (Figure 10), the answers were quite clear. Only 3 hospitals (8.8%) used this type of technology and 2 (5.9%) were actively planning to include it to perform their functions. The majority of responses (11 hospitals, 32.4%) indicated that hospitals do not use these technologies and are not interested in incorporating them into their day-to-day operations.

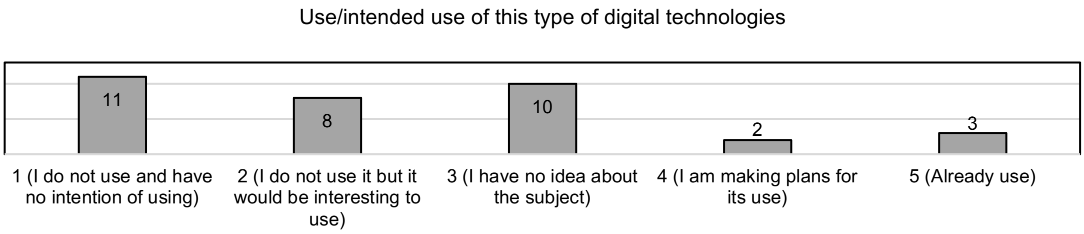

Figure 10: Answer distribution to Q20: In the hospital where you work, what is the use/intention of using this type of digital technology?

The sample had the opportunity to mention other technologies of the same category (Q21) besides Glossair 400, with Diosol Generator – Carfil Quality being referred once.

4.3.2) Electronic Health Records Systems

Two specific technologies were presented in these questions (Q22 and Q24): Monitor ICU System and MONI Support, as shown in Figure 11.

Monitor ICU System was the most familiar technology to the sample, with 6 hospitals (17.6%) having seen it working and 2 (5.9%) using it. In contrast, half of the hospitals indicated that they were not aware of the existence of MONI Support technology, while 16 (47.1%) were not familiar with it.

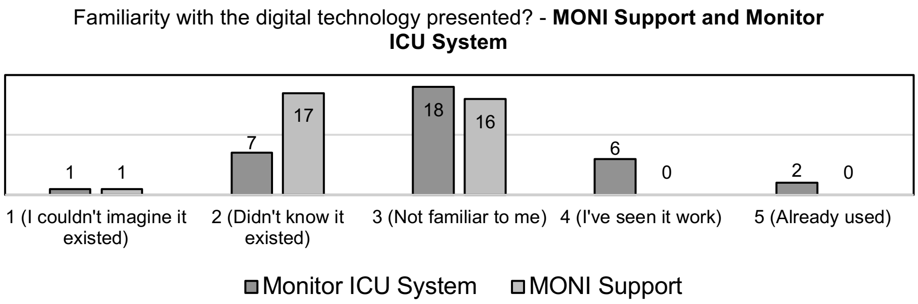

Figure 11: Answer distribution to Q22: How familiar are you with the digital technology presented in the video? (ICU Monitor System) and Q24: In this question, another digital technology with the same objective is described – MONI Support. How familiar are you with the technology presented (MONI Suport)

When asked about the use/intention to use Monitor ICU System and MONI Support (Q23 and Q25), the answers were very similar, as shown in Figure 12. Regarding Monitor ICU System technology, 13 hospitals (38.2%) had no idea about it. In comparison, the results obtained for MONI technology only differ slightly in the hospitals that had no idea about this technology (44.1%), hospitals that don't use it and have no intention of using it in the future (5.9%) and that are currently making plans to use it (11.8%).

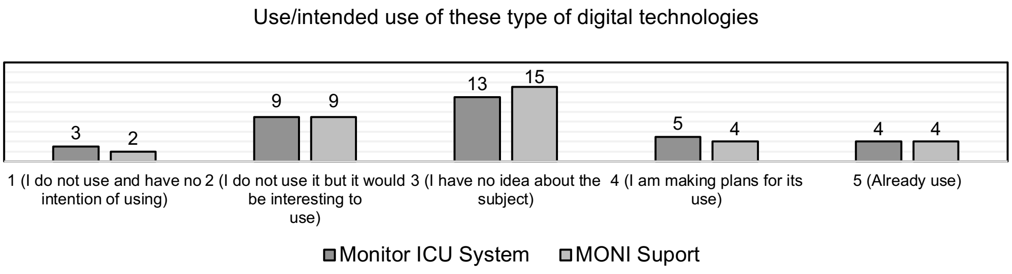

Figure 12: Answer distribution to Q23 and Q25) In the hospital where you work, what is the use/intention of using this type of digital technology?

Additionally, the sample had the opportunity to mention other technologies from the same category (Q26): PICIS Clinical Solutions was mentioned by 1 hospital; Meliora was mentioned by 2 hospitals and HEPIC was mentioned by 3 hospitals.

4.3.3) Apps for Mobile Devices

It was questioned whether hospitals use apps for mobile devices in the context of infection control (Q27): only 8 hospitals claimed to use this type of apps while 26 hospitals claimed not to use them. Those who answered “Yes” to the previous question were asked which groups of HCPs use apps in the context of infection control (Q28). Six answered to be nurses; 2 doctors and 4 HCPs who belonged to the ICC.

Subsequently it was presented a total of 13 apps used in the context of infection control to evaluate if they were recognized (Q29). The maximum of positive answers to this question was 2 while 32 answered negatively. In addition, the sample had the chance to mention other apps utilized in the same context (Q30), but the answers were not considered.

4.3.4) Electronic Hand Hygiene Monitoring Systems

Participants were asked about their familiarity with the specific EHHM-based technology, Biovigil (Q31), with the results presented in Figure 13. The majority of responses indicate that the hospitals were not aware of the existence of the technology (6 hospitals, 47.1%), followed by 12 hospitals (35.3%) indicating that it was not familiar to them.

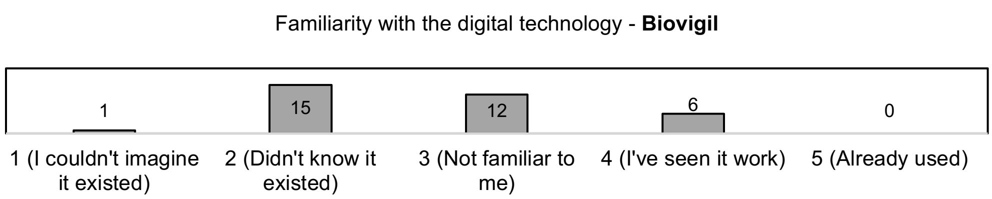

Figure 13: Answer distribution to Q31: How familiar are you with the digital technology presented in the video? (Biovigil)

However, when the question was about the use/intention to use technologies for this purpose (Q32), 19 hospitals (55.9%) admitted that they do not use them at the moment but that it would be interesting to use them in the future, as shown in Figure 14. Three hospitals (8.8%) were not interested in this type of technology, neither using it nor planning to use it in the future.

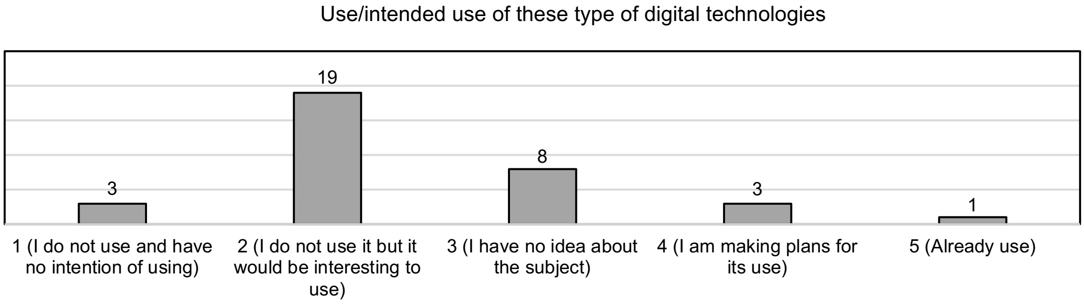

Figure 14: Answer distribution to Q32: In the hospital where you work, what is the use/intention of using this type of digital technology?

Consecutively, other digital technologies of the same category were listed with the same purpose, in order to assess whether the hospitals recognized them (Q33). Only one hospital reported to recognize one of the technologies presented: MediHandTrace. Then was then asked if it the hospitals were aware of any similar technology than the listed (Q34). All responses were negative.

4.3.5) Real-Time Location Systems

Regarding RLT based digital technologies, 27 hospitals reported not using them in their functions (Q35). Afterward, technologies for the same purpose were listed and asked if the sample recognized them (Q36): 2 hospitals claimed to have known about Zebra brand technologies and 1 hospital about Secutiras Technology brand technologies. The following question (Q37) asked was if the sample was aware of any similar technology, but all responses were negative. When asked specifically about use/intention to use this class of technologies (Q38), Figure 15 demonstrates that the responses were quite diverse. Only one hospital (2.9%) used technologies for this purpose, while other 6 (17.6%) make plans for their future use.

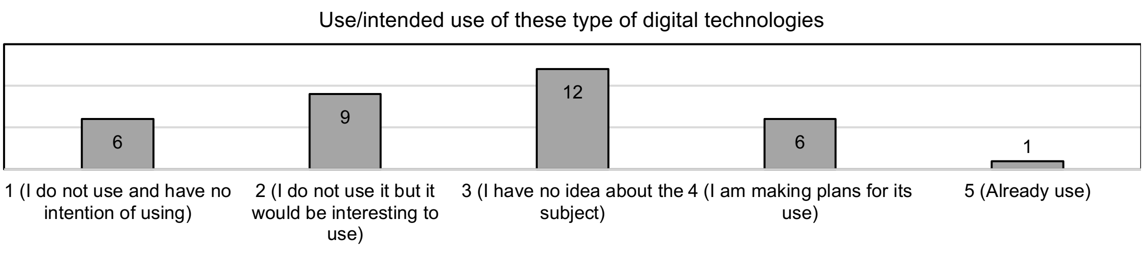

Figure 15: Answer distribution to Q38: In the hospital where you work, what is the use/intention of using this type of digital technology?

4.3.6) Artificial Intelligence Based Systems

As shown in Figure 16, the majority of hospitals do not use decision support tools based on AI (91%), with only 9% answering positively to the question (Q39).

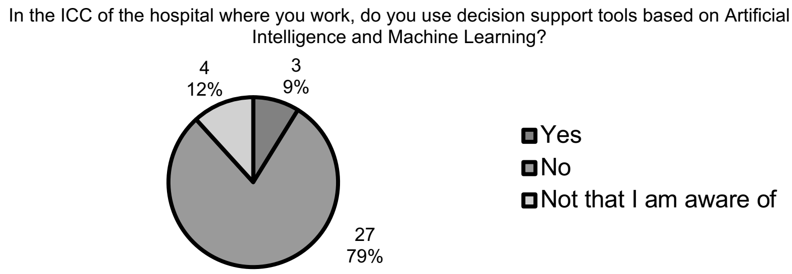

Figure 16: Answer distribution to Q39: Does the ICC at the hospital where you work use decision support tools based on Artificial Intelligence and Machine Learning?

Examples of tools based on AI were presented (Q40). As shown in Figure 17, 18 hospitals (52.9%) indicate that they do not recognize any of the tools.

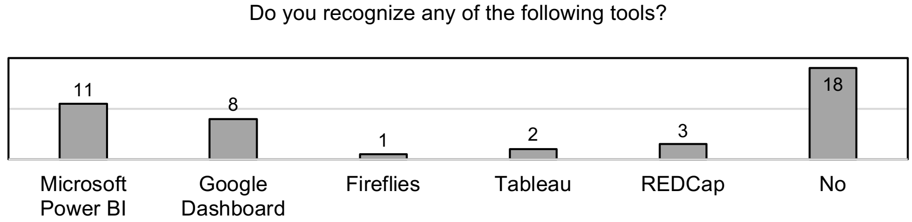

Figure 17: Answer distribution to Q40: Do you recognize any of the following tools?

The sample was then asked if they were aware of any similar technology that had not been previously listed (Q41), but all responses were negative.

4.4) Digital Transformation in Infection Control Strategies associated with healthcare

When confronted with a definition of DT (Q42), 23 hospitals (67,6%) considered their knowledge about this process to be insufficient or fairly insufficient, compared to the 11 (32,4%) that considered it to be sufficient or good, as presented in Figure 18.

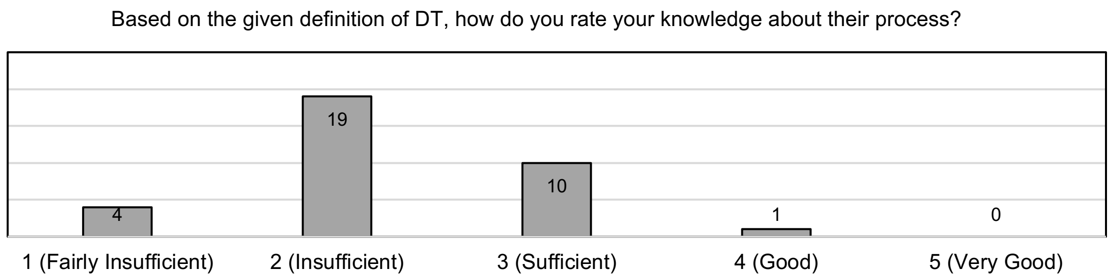

Figure 18: Answer distribution to Q42: According to C. Gong and V. Ribiere, DT is defined as "(…)." Based on this definition, how would you rate your knowledge of the DT process?

When the sample was asked about the degree of use of digital technologies in the hospital itself or by the ICC of which they are members, the results were quite similar, as demonstrated in Figure 19 and 20.

In case of the use of these technologies by the hospitals (Q43) (Figure 19), this was considered fairly insufficient or insufficient by 27 hospitals (79.4%), while it was considered sufficient, good, or very good by the other 7 (20.6%).

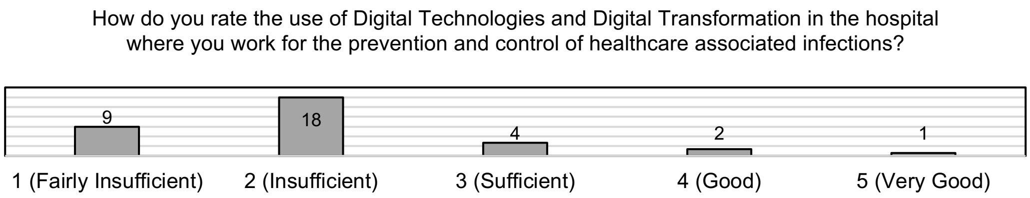

Figure 19: Answer distribution to Q43: In general, how do you rate the use of Digital Technologies and Digital Transformation in the hospital where you work for the prevention and control of healthcare-associated infections?

In case of the use of digital technologies in decision-making processes by the ICC, on Figure 20 (Q44), it was considered fairly insufficient or insufficient by 26 hospitals (76.5%), while it was considered sufficient, good, or very good by the other 8 (23.5%).

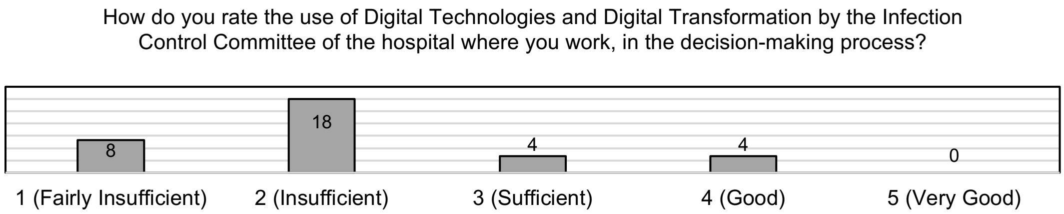

Figure 20: Answer distribution to Q44: In general, how do you rate the use of Digital Technologies and Digital Transformation by the Infection Control Committee at the hospital where you work in the decision-making process?

4.5) Perception and Attitude towards Digital Transformation

When asked about the role that digital technologies will play in the future of HAIs control (Q45), the whole sample considered it relevant, but to different degrees, as shown in Figure 21. The majority of the sample (61.8%) considered digital technologies essential in the future of HAIs control.

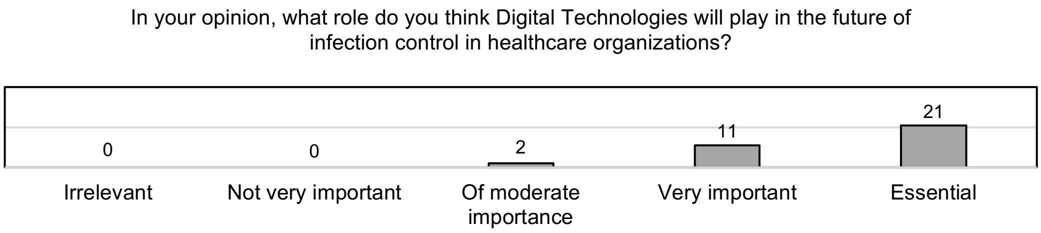

Figure 21: Answer distribution to Q45: In your opinion, what role do you think Digital Technologies will play in the future of infection control in healthcare organizations?

Figure 22 shows the main challenges encountered by ICCs in the implementation of digital technologies in their hospitals (Q46). Lack of funding was considered the biggest challenge, with 32 (97%) considering it. Lack of technical knowledge and lack of human resources were the next most pointed reasons, with a percentage of responses of 61.8% and 52.9%, respectively. Despite the examples already covered in the question, two more were described in two moments of response: Lack of prioritization by the Board of Directors and Lack of monitoring by the Directorate General of Health, as also described in Figure 21.

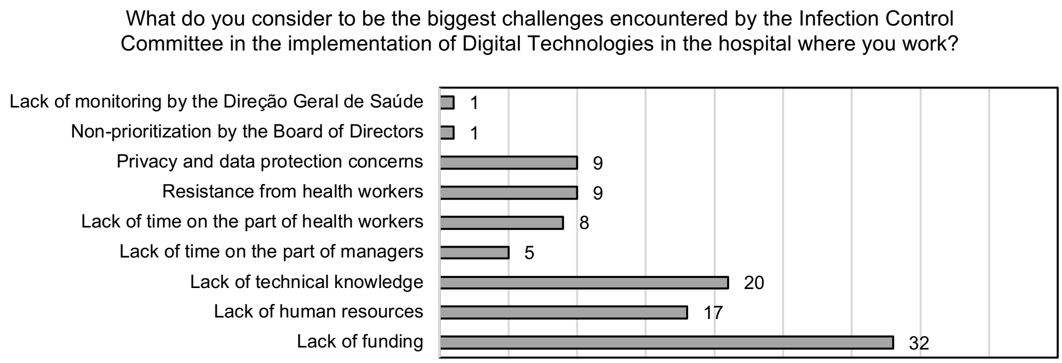

Figure 22: Answer distribution to Q46: In your opinion, what do you consider to be the major challenges faced by the Infection Control Committee in implementing Digital Technologies at the hospital where you work? Select the options you consider to be true:

The opportunities for improvement that digital technologies provide to HAIs control considered by the sample are shown in Figure 23 (Q47). All hospitals mentioned “Better data collection and analysis” as an opportunity, 33 hospitals (97%) mentioned “Gains for health, patients, professionals, health organization, national health service” and 29 (88,2%) mentioned “More effective control and prevention of healthcare associated infections”. Again, despite the examples already covered in the question, one more was described: “Immediate feedback”.

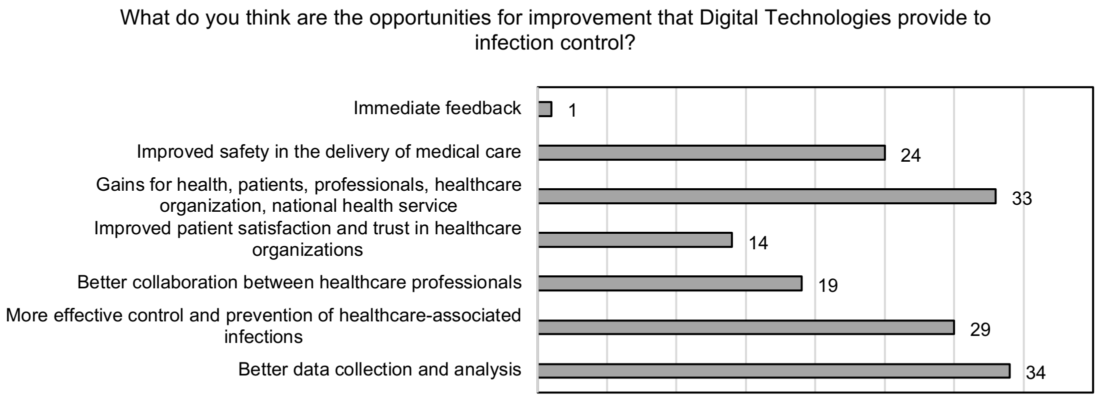

Figure 1: Answer distribution to Q47: In your opinion, what do you consider to be the opportunities for improvement provided by Digital Technologies in infection control? Select the options you consider to be true:

To finalize the questionnaire, the sample was asked if considers that digital technologies are a mean that can lead to an increase in the efficiency and effectiveness of infection control strategies in the hospital where it works (Q48). The entire sample responded positively, with 34 hospitals fully agreeing and the remaining minimally agreeing.

5) RESULTS ANALYSIS

Variables were analyzed for potential associations using the Chi-Square tests listed in Appendix E. A statistically significant result was considered when p-value was below 0,05. As can be seen in Table 3, no statistically significant correlations were identified, so no clear associations between variables were found in this small sample. Nevertheless, it is still valid to analyze some relationships that show more tendency towards association. These are present in bold in Table 3.

Table 3: Summary of the results obtained. Source: the author.

Independent Variable	Dependent Variable	X^2 (df[a])	Significance
HR	Knowledge on productivity tools	0,134 (1)	p = 0,714 (ns[b])
	Familiarity on digital technologies used in Infection Control	2,267 (1)	**p = 0,132 (ns)**
	Use/Intention to use digital technologies in Infection Control	0,180 (1)	p = 0,671 (ns)
	Knowledge on digital transformation and digital technologies	0,180 (1)	p = 0,671 (ns)
Dimension	**Knowledge on productivity tools**	0,444 (1)	**p = 0,505 (ns)**
	Familiarity on digital technologies used in Infection Control	0,003 (1)	p = 0,956 (ns)
	Use/Intention to use digital technologies in Infection Control	0,214 (1)	p = 0,644 (ns)
	Knowledge on digital transformation and digital technologies	0,344 (1)	p = 0,558 (ns)
University/ Non-University	Knowledge on productivity tools	0,192 (1)	p = 0,661 (ns)
	Familiarity on digital technologies used in Infection Control	0,379 (1)	p = 0,538 (ns)
	Use/Intention to use digital technologies in Infection Control	1,315 (1)	**p = 0,252 (ns)**
	Knowledge on digital transformation and digital technologies	1,315 (1)	**p = 0,252 (ns)**

a df, degrees of freedom

b ns, non-significant

5.1) Knowledge on productivity tools

In the present study, 23 hospitals reported a reasonable knowledge off productivity tools used by ICCs (67,6% of the sample). Regarding the dimension of the hospitals, 8 of the 11 hospitals that appear to have a lower understanding of productivity tools were large-sized hospitals (23,5% of the total sample). On the other hand, of the 23 hospitals that appear to have sufficient knowledge on productivity tools, 19 of them were once again large-sized hospitals (55,9% of the total sample). As such, it is possible to conclude that large-sized hospitals tend to have more knowledge on this topic, in accordance with the specific conditions of this study.

5.2) Familiarity on digital technologies used in Infection Control

According to the results, it was possible to determine that 10 hospitals appeared to be familiar with digital technologies used in infection control, representing 29,4% of the sample. Of the hospitals that belong to HR Centro, 3 of them (42,9% of the hospitals from this category) reported being familiar with digital technologies applied in infection control, which is the highest percentage observed. So is possible to conclude that hospitals belonging to HR Centro appear to be more familiar with digital technologies applied in infection control. Surprisingly, hospitals belonging to the HR Norte appeared not to be familiar with the digital technologies applied in this area, given that the hospitals belonging to this HR were one of the categories that demonstrated a higher knowledge of productivity tools.

5.3) Use/Intention to use digital technologies in Infection Control

Only 7 hospitals reported the use/have intention to use digital technologies in infection control (20.6%), turning this variable one of the two with the lowest percentage of positive responses. Regarding university and non-university hospitals, only 1 university hospital appears to use/have intention to use digital technologies in infection control, while 6 are non-university. The one university hospital corresponds to 9,1% of university hospitals, while the 6 non-university hospitals represent 17.6% of non-university hospitals. Therefore, is possible to conclude that non-university hospitals appear more likely to use and to intend to use in the future digital technologies in infection control.

5.4) Knowledge on digital transformation and digital technologies

Seven hospitals appeared to possess a reasonable knowledge on digital transformation and digital technologies, corresponding to 20,6% of the sample. As discussed above, this variable was one of the two that described the lower positive response. Regarding university and non-university hospitals, 17.6% of the non-university hospitals in our sample appear to have reasonable knowledge on digital transformation and digital technologies (6 hospitals), compared to only 2.9% of university hospitals in the same condition (1 hospital). Consequently, non-university hospitals appear to have a higher knowledge on digital transformation and digital technologies.

5.5) Perception and attitudes towards digital transformation

The successful implementation of DT in healthcare organizations depends on the perspectives, attitudes, knowledge, and eventual practices of their healthcare professionals.

Regarding the opinion of the ICCs on the role that digital technologies can play in the future of infection control in healthcare organizations, responses stay consistent. The entire sample considered the role of digital technologies in infection control to be of the utmost importance, as they can lead to an increase in the efficiency and effectiveness of infection control strategies. This thus confirmed the great interest that the ICCs have in the emerging issue of DT.

5.5.1) Biggest Challenges

In this study, lack of funding has been reported as the main reason for not implementing DT strategies on infection control, as only 2 hospitals did not mention this as an obstacle to implementing these measures. A total of 41% of the sample (20 hospitals) mentioned the lack of technical knowledge as a factor for not implementing digital transformation measures in this area. It's also interesting to note that 50% of the sample surveyed mentioned "Lack of human resources" as an obstacle to implementing digital transformation policies.

5.5.2) Biggest Opportunities

The greatest opportunities that the implementation of digital technologies brings to infection control in hospitals, according to the questionnaire, are the improvement of data collection methods, with 100% of the sample having this opinion, and gains for health, patients, professionals, healthcare organization and national health service, with 97,1% of the sample having this opinion. In this way, the implementation of digital technologies can lead to the implementation of innovative strategies for the collection of data relevant to medical practice and result in considerable health gains. This 97.1% are in line with what was discussed earlier, as all the hospitals mention the important role of digital technologies in infection control strategies, which once again underlines the importance that professionals attach to this topic. On the other hand, it is interesting to note that close to one third of the hospitals (29.4%; 10 hospitals) do not consider improved safety in the delivery of medical care to be an opportunity brought about by the implementation of digital technologies in this area. Thus, hospitals consider that there are advantages and gains from implementing these technologies, but do not relate digital to quality of care, i.e., that digital transformation may not mean an improvement in safety in the delivery of medical care. Exploring this in depth, by means of interviews for example, could provide additional insights.

6) DISCUSSION

6.1) RQ1: What evidence exists on the use of digital technologies in infection control strategies?

From our study and regarding all the digital technologies categories presented, only 7 hospitals reported to use/have intention to use digital technologies in infection control (20.6%), turning this variable one of the two with the lowest percentage of positive responses.

Within the ADS category, HPV systems were the ones that showed the greatest interest in their future use and that are currently the most used by the sample. A similar situation is seen with UV-C based systems, with very positive results considering the use and interest in using this type of technology in this area, even though a significant number of hospitals reported not using them or showing any interest. The positive use and interest to use UV-C based systems can be due the fact that these technologies are the easier to use within this category, so the level of technical knowledge needed by the HCPs is lower (Otter et al., 2019). On the other hand, vapor-based systems are the more efficient, which is a possible justification of the higher interest shown by the sample (Otter et al., 2019). Regarding systems based on aHP, the majority of the sample does not use this type of technology in their practices, or does it show interest in using it in the future. The general interest seen in this category of technologies could be explained by the high number of research around this topic that is emerging recently (Otter et al., 2019).

Regarding EHR systems, most responses indicated that the sample does not recognize this type of technology as a potential use in the context of infection. Although the potential of EMRs on healthcare, the level of adoption of these technologies is comparatively low (Abdekhoda et al., 2016), what is in line with the results obtained on this study. This may be due to financial challenges, lack of technical knowledge and changes in work methodology (Abdekhoda et al., 2016). The first two reasons mentioned are in line with the results of our study, as they were issues pointed out as possible obstacles to the implementation of these technologies in the context of infection control.

Concerning Apps for mobile devices, only a small percentage claimed to use them. Despite apps being a fast and efficient tool for a variety of health-related issues, their implementation and acceptance remains a barrier, with the stakeholders on around this problem considering difficult to people (especially HCPs) to use their apps (Chakraborty & Paul, 2023). Despite the benefits offered, new guidelines and validation techniques for mobile medical applications are required to guarantee proper deployment and integration of these increasingly sophisticated tools into clinical practice. This may be a possible justification for the low percentage shown on this research results, highlighting the fact that only two doctors claimed to use these technologies.

Electronic Hand Hygiene Monitoring Systems was the category of digital technologies in which the sample was most interested in using in the future. This may be due to the fact that HH is one of the basic topics of a good IPC strategy, as mentioned in the Multimodal Strategy for the Promotion of Basic Infection Control Precautions (Lebre et al., 2023). The Portuguese HH Campaign began in 2008, but in 2014, PPCIRA extended it to a broader framework (Lebre et al., 2023), which may justify the interest of ICCs in this category of technologies.

Regarding RTL systems, most responses indicated that the hospitals in the sample had no idea/opinion about these technologies, although a significant number of hospitals were interested in using them in the future. However the advantages these solutions present and their desire by HCPs, this large-scale adoption is still distant (Bazo et al., 2021; Griffin et al., 2020), which is in scope with the results obtained. Is argued that, in addition to cost, the slow adoption and unsuccessful implementation attempts have been caused by a limited and narrow focus on implementation (Griffin et al., 2020).

The results revealed that the majority of the surveyed hospitals do not use AI based technologies. Although there has been an increased interest concerning these technologies (Iqbal et al., 2021; Muehlematter et al., 2021), these breakthroughs are being adopted slowly (Yousef Shaheen, 2021). There are projects underway in Portugal through these systems, like "Derm.AI - Use of Artificial Intelligence in Teledermatology" and "SNS24 PathScout.AI - Use of AI and PLN in the TAE Service at SNS24". Thus, despite the existence of these programs, this issue is not yet fully integrated in our hospitals, given the results obtained.

6.2) RQ2: What is the impact of the use of digital technologies in infection control?

Digital transformation intricacy and breadth make addressing to their impact a difficult task (Ricciardi et al., 2019). Digitalization of health has had a significant impact and is projected to have an even greater influence in the future (Ferrara et al., 2022; Ricciardi et al., 2019). Digital technologies have the potential to significantly improve the speed and accuracy of HAIs diagnostics, surveillance, and response, reducing morbidly and mortality rates, as well as their consequences (Ferrara et al., 2022). When analyzing the benefits and potential dangers of implementation in healthcare organizations is critical to understand the range and the different type technologies accessible, as well as contextual insights such as disease and geographical areas of application, because the impact will depend on it (Ali et al., 2021).

Although there is not much literature on the direct effects of DT on HAI rates, there are articles that discuss the impact of specific technologies on these rates.

Concerning AD systems, exists literature exploring the effectiveness of UV-C systems on HAIs (Astrid et al., 2021; Browne et al., 2020; S. Kelly et al., 2022; Martinello et al., 2018; Steele et al., 2021; Yang et al., 2019), aHP (S. Kelly et al., 2022; Weber et al., 2016b), HPV (Weber et al., 2016) and PX-UV (Otter et al., 2013, 2019; Simmons et al., 2021). EHRs, by identify and monitor HAIs will have an impact on their rates on long term (Behnke et al., 2021; Lo et al., 2014). Apps for mobile devices, when consistent developed, can impact indirectly HAIs by proving clear guidelines, helping monitor HH or even outline methodologies to prevent these infections (Schnall & Iribarren, 2015). HH compliance is widely considered as the most critical component in reducing infection transmission to patients in health care settings. So, EHHM systems are crucial to reduce these infections (K.-R. Cawthorne & Cooke, 2021; J. W. Kelly et al., 2016; Knudsen et al., 2021; Meng et al., 2019; Worlikar et al., 2022). HAI-reduction requiring RTL systems is a recent strategy used by healthcare organizations. These systems can impact the percentage of HAIs indirectly, as better localization of specific HCPs or even of assets can be crucial in the infection cycle (Bazo et al., 2021; Dufour et al., 2017). AI based systems can facilitate surveillance of these infections, helping identifying trends and predict the risk of possible infection, impacting HAIs (Fitzpatrick et al., 2020; Scardoni & Odone, 2019).

The results of this questionnaire can’t determine the clinical impact of technology adoption on infection control. This question could have been directly answered if a more practical investigation had been conducted. It might be conceivable to measure the impact of digital technologies in a "case study" kind of research, with digital technologies introduced in a healthcare organization and HAI rates are evaluated. This would be a relevant form of research, but it would be more appropriate for a higher academic level, such as a PhD.

6.3) Does digital transformation of infection control strategies have a financial impact?

Several factors must be considered when evaluating the implementation of digital technologies on healthcare facilities, with the cost being one of those (Otter et al., 2019). Although cost-effectiveness, efficiency, and usability will depend on the specific technology and their implementation (Gopidasan et al., 2022), studies directly comparing disinfection modalities and cost benefits are limited (Dancer & King, 2021; Gopidasan et al., 2022). This can be seen in this study on AD systems, where of fourty-three studies reporting patient benefit from using automated devices systems, only seven present financial data, albeit not significant (Dancer & King, 2021). A review on EHRs was made, and no cost-effectiveness conclusions could be made because the underlying studies had mixed and ambiguous findings (Reis et al., 2017). Regarding eHealth, there aren't many studies on cost-effectiveness (de la Torre-Díez et al., 2015; Ghani et al., 2020). However, not all cost-effectiveness studies show that telemedicine can cut costs (de la Torre-Díez et al., 2015; Whitten, 2002). EHHM systems are expensive, especially if hospital-wide implementation is done (Ward et al., 2014). Studies regarding the cost-effectiveness of these category of technologies are limited (Ward et al., 2014), that underlines the reluctance of stakeholders to financially support investment in these digital technologies (K.-R. Cawthorne & Cooke, 2021). Considering RTL systems, a study conducted by the University of California Medical Center in San Diego has been using an RFID-based location system to track various assets. The hospital estimates that this technology has saved near USD 70,000 a year just by identifying the location of intravenous pumps (Rostkowski & Banat, 2020). Even though the cost of the RTL systems can be justified in large-sized healthcare organizations, is possible that this is argued between smaller-sized ones (Rostkowski & Banat, 2020), so is necessary to deeply evaluate the implementation of these digital technologies. AI based technologies are still in cost-effectiveness evaluation (Lee & Yoon, 2021). Although the use of AI may lead to better patient disease treatment outcomes, it is not currently intended to fundamentally enhance healthcare services or substantially lower costs (Miyashita & Brady, 2019). Nonetheless, a new AI-based method has been developed to replace the conventional procedures, turning the diagnosis and treatment processes faster and more cost-effective (Escalante et al., 2012).

6.4) What is the perception and experience of Portuguese Hospitals related to digital technologies of infection control?

The high number of questionnaire responses points to a growing interest of HCPs in DT. The questionnaire rejection rate (10.5%) was low, thus being possible to concluded that the questions were developed effectively. It is important to note that, given the non-mandatory questions, there was a relatively good response. This is another strong indicator of the sample's interest in the questionnaire and the topic it covered.

Geographic location, competitiveness, hospital size, and occupancy rate have been described as the primary contributors to hospital profitability and performance (Younis et al., 2006). As such, one of the main objectives of this study was to analyse their possible impact on knowledge and opinion of ICCs on DT. The variable "University/Non-University" was also analyzed since the potential different level of efficiency is eminent.

Portugal has been increasingly adopting digital technologies in its clinical practices, especially after the COVID-19 pandemic (Portela et al., 2021). This adoption has been occurred at varying rates, according on the areas of activity, the types of sectors involved, and the legal regime of the organization, among other variables (Teixeira et al., 2023). However, the technological distribution in Portugal is asymmetrical (Lapa & Vieira, 2019). One way of analyzing this non-uniform distribution throughout Portugal is to look at the regional distribution of companies in the ICT sector (Melo Campos, 2019). The Lisboa e Vale do Tejo region is dominant, with 48% of the companies in this sector based in this region. This figure drops to 28% regarding Norte and 20% regarding Centro. These rates can be used to verify that, as the population in the Lisboa e Vale do Tejo area is more familiar with concepts related to DT, this can be transposed to the health area (Melo Campos, 2019). This is in line with our results, as the largest number of responses came from hospitals belonging to the HR Lisboa e Vale do Tejo, followed by the HR Norte and HR Centro. Bearing in mind that the HR with most hospitals contacted during this study was HR Norte (31 hospitals), it would be expected that the highest percentage of responses would originate from this group of hospitals, which was not the case.

The number of beds can potentially impact a hospital function, as there is still no consensus to whether large-sized hospitals are more or less efficient then small-sized ones (Ravaghi et al., 2020). Regarding the number of beds available in each of the hospitals that took part in the present study, large-sized were more participative (82,4% of the sample). This was expected, as the majority of hospitals that received the questionnaire were the large-sized ones. The high response rate of this group of hospitals could also be attributed to their higher number of human resources, as the constitutions of the ICCs.

Despite the substantial disparities that exist between public and private hospital sectors, there are enough similarities between them to justify comparisons (Productivity Commission, 2009). Despite this, only one hospital in the sample was private. A possible justification for this could be the differences in organization that exist between these hospitals and public ones. These differences have led to the vast majority of the questionnaires sent to private hospitals were sent to their general email, instead of being directly sent to ICCs.

A crucial part of the healthcare system is university hospitals. They serve as important centers for learning and research, being crucial in the advancement of clinical care. However, not everyone has known they actually provide care of a greater caliber than that provided by non-university hospitals (Kupersmith, 2005). Bearing in mind that, to date, there are only 7 university hospitals in Portugal (Serviço Nacional de Súde, 2023), it was a surprise to see that 11 hospitals reported being university hospitals. This may be due to the fact that the questionnaire was sent to several hospitals belonging to the same University Hospital Center, since these are made up of more than one hospital unit.

The idea that adhering to accrediting criteria provides numerous tenable advantages in enhancing performance in the hospital setting is supported by academics (Hussein et al., 2021). Nonetheless their positive impact should be interpreted with caution (Araujo et al., 2020). Scientific evidence claims that hospital certification programs encourage performance improvement and increase patient safety, despite conflicting causal data (Hussein et al., 2021). Taking into account the certification and accreditation of the hospitals surveyed, 44% of them reported having some kind of certification/accreditation.

Given the apparent greater knowledge of productivity tools of large-sized hospitals, this could be due to the fact that these hospitals necessarily deal with a greater volume of patients, and consequently HCPs, and more complex services. Therefore, as effectiveness and efficiency levels must be particularly high in these hospitals, there may be a need to adopt more productivity tools in order to help this process.

In view of the most recent prevalence report in acute hospitals in Portugal, when analyzing the distribution between different types of infection by HR, HR Centro shows levels of infection below the national average in all parameters (Paiva et al., 2021). The fact that the hospitals in our sample belonging to this HR are the ones that appear to be most familiar with digital technologies used in infection control is a possible explanation for this fact.

Developments in ICTs are dramatically altering the nature of future medicine, with the existing classroom model appearing to be having difficulty fully educating students for the future of medicine (Park et al., 2021). Several teaching strategies that use new technology to improve immersion are currently emerging. However, the DT process can become more complex in this type of institutions, as other groups need to adapt: the medical students and their teachers. Regarding bureaucracy, the association with universities may bring more challenges, e.g., biggest financial obstacles buying these technologies. This may be a reason why the level of use/intention to use digital technologies in the context of infection control and the knowledge on digital transformation and digital technologies appeared to be higher in non-university hospitals, regarding this study.

New scientific knowledge, processes and innovation are usually slow to disseminate (Balas & Chapman, 2018). Organizations, especially healthcare ones, have more difficulty adopting DT processes since they are the sum of their individuals and own system with its specific set of procedures and standards (Balas & Chapman, 2018; Konopik et al., 2022). Therefore, since all organizations are different, their degree of adoption of new technologies will also be different. This is consistent with Rogers' Diffusion of Innovation theory (Everett M. Rogers, 2003), which is predicated on the assumption that the acceptance of innovations is a gradual process, with different groups of individuals accepting the innovation at different times. When applying this theory to the context of DT process, is possible to observe different levels of adoption and advancement in the use of digital technologies on healthcare organizations. These levels often correspond to the stages of the innovation diffusion process, as described by Rogers. These are classified as innovators, early adopters, early majority, late majority, and laggards. Although the healthcare industry is complex and these phases are not completely linear, this theory is also capable of justifying the different levels of the parameters assessed in this study, such as familiarity with digital technologies and their use/input in the context of infection control.

The part of leadership in carrying and supporting an organization through a digital evolution is critical (R.-L. Larjovuori et al., 2018), since adopting new technologies is only one aspect of DT. It is needed an inclusive plan that spans the entire organization, from top to bottom, since a successful DT depends on how leaders decide to use digital technology for the growth of the organization (R. L. Larjovuori et al., 2018; Sainger, 2018). Changes in culture, practices, and thinking are required, so hospital managers have an important role in these decisions (Sainger, 2018). Managers must grasp the organization's goals and objectives, question their functioning, engage their employees in the process of redefining their job responsibilities, and be open to the prospect that their own roles will change as well (R.-L. Larjovuori et al., 2018; Sal, 2023). They also need to ensure how digital technologies might aid in their attainment, creating a comprehensive digital transformation strategy that covers all parts of the business (Sal, 2023).

Since ICCs are an integral part of a hospital's organizational structure, these guidelines will also extend to them, giving them reinforcement in applying their measures as effectively and efficiently as possible. By creating a strategy focused on the application of DT in this area, the members of these committees would be able to apply digital technologies in a more centralized way, making the most of them for the benefit of the organization.

7) LIMITATIONS AND FUTURE WORK

Sample size could always have been higher but overall response rate obtained in this research was significant for this type of studies.

The main objective of this questionnaire was to gather different insights and viewpoints regarding a new and complex topic. As such, some of the participants might not be familiarized with such topic, resulting in a negative bias in some of the responses. In an effort to lessen that bias, a straightforward questionnaire was constructed, with some questions including explicative videos and/or links to the commercial site of the technologies. This was done with the intent of properly familiarizing participants with all the technologies mentioned during this study.

Given the multidisciplinary nature of ICCs, it is natural that the degree of knowledge differs. As the questionnaire was sent either to the ICCs general email address or even to the hospital's general email address, it was impossible to guarantee that questionnaires were answered by the committee members with more experience regarding this subject. In view of this, it would be useful to ensure that the president of the commission himself was the one who answered the questionnaire, during future studies.

The findings and the logic of this research could be relevant for future qualitative studies (employing methods like participant observation, focus groups, or interviews), since every respondent had different experiences and opinions. This would contribute to a deeper understanding of current practices and prospective patterns in DT. For example, this could be achieved by implementing certain digital technologies in a hospital and tracking its infection data.

Future research would also benefit from a more in-depth exploration of the organization demographics/context, achieved by conducting similar studies in environments where digital technologies were well established. This would make it possible to distinguish between hospitals who reject digital technologies out of choice and those who do so because they have no other options. Furthermore, it would be important to comprehend the knowledge and perceptions that ICCs that have access to digital technologies and those that don’t. In the future, it would be interesting to implement the questionnaire developed for this study in other countries, where more data and evidence around their knowledge and perceptions on DT are available.

In a "case study" type of research, in which a digital technology is implemented in a healthcare organization and pre- and post-implementation costs are compared, it would be possible to assess cost/economic impacts. This would be an interesting and extremely pertinent type of study, but it would be suitable for another academic level, such as a PhD.

8) RECOMENDATIONS

8.1) For Infection Control Committees (GCL-PPCIRA)

- Crucial to understand the specific needs of the healthcare institution and to form an interdisciplinary team. The ongoing training is also important.
- Constant updating on digital technologies applied in this context, ethical and legal standards are indispensable practices for the success of DT in infection control.

8.2) For Healthcare Organizations

- DT must be incorporate on management methods, building a work culture that is receptive and aware to new technologies - boost for all stakeholders, motivating them to invest in these new methodologies.
- Appropriate investment in adequate resources, both in terms of providing adequate levels of knowledge to HCPs and in terms of adequate infrastructures.

8.3) For Education

- Digital transformation needs to be approached through the entire health education system for it to become prevalent in the healthcare system.

8.4) For Countries - National Policy

- Digital health systems play a critical role in support of public health policies.
- To increase trust in the use of new DT methodologies, the Government, in particular the Ministry of Health and the Directorate General of Health, should commit to develop a legal framework that includes and regulates the use of digital technologies in the context of infection control. Is also important the establishment of strong leadership commitment and action-oriented political engagement so that policies are in place that demand the scaling up and enforcement of the essential elements for IPC strategies.

8.5) For World Health Organization (WHO)

- WHO have a major role in health care worldwide, with general efforts involving standards, surveillance, research, capacity building, vaccination, and infrastructure development, significantly impacting infection control worldwide.
- WHO should strive to establish IPC guidelines and standards, ensuring that these are practiced in an active and strong way. These should be coordinated with other health priorities and programmes and integrated into patient pathways and medical care.

9) CONCLUSIONS

Despite rising interest in DT applied to the control and prevention of HAIs, its integration into healthcare organizations and their practices is still a quite new process, with some obstacles delaying its full implementation. HCPs are the agents of change in this matter, so understanding their knowledge and perception of DT is crucial.

Findings from this study:

- No statistically significant relationship was found among the variables discussed. However, some notable trends emerged regarding the attitudes and knowledge of HCPs toward DT in infection control.

Key findings include:

- Greater knowledge of productivity tools of large-sized hospitals.
- HR Centro hospitals appear to be most familiar with digital technologies used in infection control.
- Use/intention to use digital technologies in the context of infection control and the knowledge on digital transformation and digital technologies appeared to be higher in non-university hospitals

Main obstacles for implementing DT strategies in infection control include:

- Lack of funding.
- Insufficient technical knowledge.
- A shortage of human resources.

Advantages of Implementing DT include:

- Improved data collection methods and benefits for health, patients, professionals, healthcare organizations, and the National Health Service.

Significance and Future Research:

- The findings can aid decision-making processes at the board level and inform best practices for successful DT implementations. Additionally, this study serves as a foundation for future research and can be applied to hospitals in different countries.

The Potential of DT:

- Increase diagnostic accuracy and speed, enable efficient data storage and presentation, and reduce the burden of time-consuming tasks.
  Enhance the productivity of ICCs.

Collaborative Efforts for DT:

- All stakeholders must work together under a well-defined DT plan, focusing on improving the overall effectiveness of healthcare services, benefiting both patients and healthcare professionals.

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11) APPENDIX

APPENDIX A – Email sent to the general email of target Hospitals.

Dear Sirs,

My name is Mariana Domingues. I am currently conducting my thesis as part of the master's program in Healthcare Services Management at ISCTE-IUL, under the guidance of Professor Henrique Martins.

This study addresses the topic of Digital Transformation applied to Infection Control Strategies in Healthcare. The main objective of this study is to understand the impact of digital transformation on infection control strategies associated with healthcare in Portuguese hospitals, specifically focusing on their Infection Control Committees.

In order to make this work more interesting, a questionnaire has been developed, targeting the Infection Control Committees of Portuguese hospitals. They will be surveyed about their level of digital transformation, with questions specifically related to the use of digital technologies and their perception and attitudes towards digital transformation.

Attached is the link to the questionnaire: X

The deadline for responding to the questionnaire will be July 10th. I am also attaching a document that provides a theoretical framework on the topic and the research questions of this study, in case you find it relevant.

Therefore, I kindly ask if you could forward this email to the Infection Control Committee of your hospital, if possible. It would be highly valuable for my study, and I would greatly appreciate it.

If you have any further questions, please do not hesitate to contact me via email at mndss1@iscte-iul.pt or by phone at 924021862.

Thank you for your participation and best regards.

Mariana Domingues

APPENDIX B – Email sent to the specific Members of Infections Control Committees (when contact available)

Dear Members of the Infection Control Committee,

My name is Mariana Domingues. I am currently conducting my thesis as part of the master's program in Healthcare Services Management at ISCTE-IUL, under the guidance of Professor Henrique Martins.

This study addresses the topic of Digital Transformation applied to Infection Control Strategies in Healthcare. The main objective of this study is to understand the impact of digital transformation on infection control strategies associated with healthcare in Portuguese hospitals, specifically focusing on their Infection Control Committees.

In order to make this work more interesting, a questionnaire has been developed, targeting the Infection Control Committees of Portuguese hospitals. They will be surveyed about their level of digital transformation, with questions specifically related to the use of digital technologies and their perception and attitudes towards digital transformation.

Attached is the link to the questionnaire: X

The deadline for responding to the questionnaire will be June 20th. I am also attaching a document that provides a theoretical framework on the topic and outlines the research questions of this study, in case you find it relevant.

Therefore, I kindly request your participation in completing the survey. Your input would be of great assistance to my academic journey and the success of my study.

If you have any further questions, please do not hesitate to contact me via email at mndss1@iscte-iul.pt or by phone at 924021862.

Thank you for your participation and best regards.

Mariana Domingues

APPENDIX C – Document attached to emails sent to the study sample.

The increase in the use and dependence on digital technologies introduces significant changes, both in the business and society. In this sense, the concept of digital transformation is introduced to discuss these changes.

For many years, the healthcare industry has been one of the main targets of digital transformation, increasing the relevance of the topic for both academics and professionals in the field.

Digital transformation applied to healthcare has resulted in important advantages, with the adoption of new technologies that contribute to the provision of safe and high-quality healthcare to patients and lead to superior business efficiency. The last two decades have been characterized by fast spread and use of digital technologies in various domains of public health, with many organizations and healthcare systems adopting digital technologies in their various functional areas.

Developments in information and communication technologies, especially in digital transformation, have the power to improve key functions associated with public health, such as infection control.

Healthcare-associated infections are a critical issue affecting all healthcare organizations, as they are common causes of illness and mortality among hospitalized patients, with a prevalence ranging from 5 to 15%. Several efforts have been made to reduce these values, with literature affirming that a significant number of healthcare-associated infections are preventable.

Transformation and digital technologies have the power to have a drastic impact on this type of infection by improving infection control practices, increasing the efficiency and effectiveness of their prevention and management, and enhancing patient safety.

However, it is crucial to be aware that the impact of digital transformation on these infections will depend on the specific technologies implemented, the quality of implementation, and the context in which they are used.

There are several digital technologies that are commonly used in infection prevention and control, which can be mainly grouped into six categories:

- Automated disinfection systems
- Electronic health records
- Applications for Mobile Devices
- Electronic Hand hygiene Monitoring Systems
- Real-Time Location Systems
- Artificial Intelligence

Literature suggests that these technologies have the potential to significantly improve infection control strategies and reduce the incidence of healthcare-associated infections. The potential benefits of these technologies are clear, and healthcare organizations that adopt digital technologies for infection control will show significant improvements in patient safety, directly reducing the percentage of these infections.

The aim of this study is to understand the impact of digital transformation on infection control strategies associated with healthcare in Portuguese hospitals, specifically in their Infection Control Committees. The focus of this research is Portuguese hospitals from the seven Regional Health Administrations (RHA) in Portugal.

Throughout this investigation, four research questions will be highlighted. This study aims to answer the following:

- What scientific evidence exists regarding the use of digital technologies in infection control strategies associated with healthcare?
- What type of impact do digital technologies have on infection control associated with healthcare?
- Does digital transformation in infection control strategies have a financial impact on the healthcare environment?
- What is the opinion and experience of Portuguese hospitals regarding the use of digital technologies in infection control associated with healthcare?

The first three questions will be answered through a literature review on the subject. To answer the last question, the Infection Control Committees of Portuguese hospitals will be contacted, and they will be asked to respond to a questionnaire and, if possible, to conduct a video conference interview.

This questionnaire will be conducted through Google Forms and will last approximately 15 minutes.

Any member of the Infection Control Committee can respond to the questionnaire. The deadline for submitting responses is June 20th.

Best regards and thank you for participation
Mariana Domingues

APPENDIX D – Questionnaire Script

Dear participant,

The present study arises within the scope of a research project for the development of a master's dissertation, taking place at ISCTE - Lisbon University Institute, supervised by Professor Henrique Martins.

The study was designed by Mariana Domingues, a student of the Master's in Health Services Management (mndss1@iscte-iul.pt), available for contact in case of any questions or comments, or to receive information about the study's completion. The thesis is supervised by Dr. Henrique Martins (ISCTE-IUL).

The objective of this study is to understand the impact of digital transformation on the strategies for controlling Healthcare-Associated Infections in Portuguese hospitals, specifically in their Infection Control Committees. The focus of this research is on Portuguese hospitals belonging to the 7 Regional Health Administrations (RHA) of Portugal: RHA Norte, RHA Centro, RHA Alentejo, RHA Lisboa e Vale do Tejo, RHA Algarve, RHA Madeira, RHA Açores. By understanding the role of digital transformation and specific digital technologies, it is possible to strongly implement these practices, thus reducing the percentage of healthcare-associated infections in our hospitals.

This questionnaire should be answered by a member of the Infection Control Committee / GCL-PPCIRA.

Your participation in the study will consist of honestly answering this questionnaire. It includes closed-ended and short-answer questions, divided into 5 sections: the first section where a simple characterization of the healthcare organization in question will be carried out; the second section about productivity tools used by the Infection Control Committees; the third section about digital technologies used in infection control; the fourth section will address questions about the application of digital transformation in strategies for controlling healthcare-associated infections, and it will culminate with the fifth section that will include questions about the participant's perception and attitude towards digital transformation. The average time required to complete the entire questionnaire is 15 minutes.

No significant risks are expected from participating in this research, as it is strictly voluntary. As a participant, you can decide whether or not to participate in the study and can discontinue it at any time without providing any justification. In addition to being voluntary, participation is also anonymous and confidential.

The collected data is strictly intended for statistical analysis, and no individual responses will be analyzed or reported. At no point during the research will you need to identify yourself.

By responding to the questionnaire and submitting it, you declare that you have understood the objectives outlined by the researcher, have been given the opportunity to ask any questions about the present study, and have received clarifying answers to all of them, thus accepting to participate.

Thank you very much for your participation in this study.

Section 1: Hospital Characterization

Q1) To which Regional Health Administration (RHA) does the hospital where you work belongs to:

- RHA Norte
- RHA Centro
- RHA Alentejo
- RHA Lisboa e Vale do Tejo
- RHA Algarve
- RHA Madeira
- RHA Açores

Q2) What is the total number of beds available at the Hospital where you work (regardless of the type of healthcare)?

- < 100
- Between 100 and 200
- Between 200 and 500
- > 500

Q3) Is it a hospital under the National Health Service?

- Yes
- No

Q4) Is it a University Hospital?

- Yes
- No

Q5) Is it a certified/accredited hospital?

- Yes
- No

Q6) If you answered "Yes" to the previous question, what is the certification/accreditation model of the hospital where you work, and in which year was it awarded?

R: (open answer)

Section 2: Productivity Tools used in the Infection Control Committees

Infection Control Committees can use various productivity tools to improve their effectiveness and efficiency.

Q7) In this question, productivity tools are listed. How familiar are you with them?

Outlook; Gmail; Microsoft 365; Sapo Mail; Microsoft Word; Microsoft PowerPoint; Microsoft Excel; OneNote; Trello; Asana; Microsoft Project; Zoom; Skype; Slack; MicrosoftTeams; Google Workspace; eLearning; Moodle; Canvas; GoogleDrive; DropBox; SharePoint; OneDrive

1 (I am not familiar with the tool and have only used it occasionally/never used it)
2 (I am not familiar with the tool and have used it a limited number of times)
3 (I feel minimally familiar with the tool and use it occasionally)
4 (I feel familiar with the tool and use it regularly)
5 (I feel very familiar with the tool and use it constantly)

Q8) Are you aware of any/use any other productivity tool that is not listed above? If yes, please specify:

R: (open answer)

Q9) How would you rate the general level of productivity tool usage by the Infection Control Committee of the hospital where you work?

- 1 (Very insufficient)
- 2 (Insufficient)
- 3 (Sufficient)
- 4 (Good)
- 5 (Very good)

Q10) Based on your knowledge of Infection Control Committees in Portuguese Hospitals, which hospital do you imagine uses these tools the most?

R: (open answer)

Section 3: Digital Technologies used in Infection Control

There are several digital technologies commonly used in the prevention and control of infections in healthcare organizations. These can be principally grouped into different categories:

- Automated disinfection systems;
- Electronic health records;
- Mobile applications;
- Electronic hand hygiene monitoring systems;
- Real-time location systems;
- Artificial Intelligence-based systems.

This section is divided into 6 subsections, with questions about specific digital technologies in each category. These questions are accompanied by illustrative examples and a website with commercial information about the illustrative product.

Section 3.1: Automated Disinfection Systems

Section 3.1.1: Ultraviolet (UV) Based Automated Disinfection Systems

Before answering the following question, watch the short video at the link: https://www.youtube.com/watch?v=LBtUi34FgQE&t=1s&ab_channel=Tru-DSmartUVC

Q11) How familiar are you with the digital technology presented in the video? (Tru-D SmartUVC)

- 1 (Couldn't imagine it existed)
- 2 (Didn't know it existed)
- 3 (Not familiar with it)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q12) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (I don't use it and have no intention of using it)
- 2 (I don't use it, but it would be interesting to use it)
- 3 (I have no formed opinion on the subject)
- 4 (I am planning to use it)

- 5 (I already use it)

Q13) In this question, other digital technologies with the same objective are listed. Have you heard of any of them? If yes, select which one(s):

- THOR UVC Sterilization Robot (https://www.finsentech.com/products/thor-uvc)
- ARTZ 2.0 Mobile UVC Solutions (https://uvlightsolutions.com/products/artz-2-0%C2%AE-mobile-room-uvc-germicidal-solution)
- Optimum-UV Enlight (https://www.medicalexpo.com/pt/prod/eleri-healthcare/product-99507-835313.html)
- Hyper Light Disinfection Robot (https://www.mediland.com.tw/products-uvc-disinfection-robot-hyper-light)
- Steriliz R-D Rapid Disinfector (https://rduvc.com/)
- The TORCH (https://www.clordisys.com/torch.php)
- Sanuvox (https://sanuvox.com/em/medical/surface-and-room-disinfection/asept2x/)
- Surfacide Helios System (https://www.surfacide.com/helios)
- PATHOGON® UV Disinfection System (https://www.steris.com/healthcare/products/sterile-processing-department-accessorieelerik-on-uv-disinfection-system)
- None

Q14) Are you aware of any other similar technology that is not listed in the previous question? If yes, indicate which one(s):
R: (open answer)

Section 3.1.2: Hydrogen Peroxide Vapor-based Automated Disinfection Systems (H_2O_2)

Before answering the following question, watch the short video at the link: https://www.youtube.com/watch?v=ZN1YjK6LyiY&ab_channel=STERISLifeSciences

Q15) How familiar are you with the digital technology presented in the video? (Steris VHP systems)
- 1 (Couldn't imagine it existed)
- 2 (Didn't know it existed)
- 3 (Not familiar with it)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q16) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (I don't use it and have no intention of using it)
- 2 (I don't use it, but it would be interesting to use it)
- 3 (I have no formed opinion on the subject)
- 4 (I am planning to use it)
- 5 (I already use it)

Q17) In this question, other digital technologies with the same objective are listed. Do you recognize any of them? If yes, select which one(s):

-Bioquell BQ-50 (https://www.bioquell.com/healthcare/systems-and-services/bioquell-bq-50/?lang=en-uk)
- Synexis DHP Products (https://synexis.com/products/synexisbiodefensesystem/)
- No

Q18) Are you aware of any other similar technology that is not listed in the previous question? If yes, please indicate which one(s):

R: (open answer)

Section 3.1.3: Automated Disinfection Systems based on hydrogen peroxide (H_2O_2) aerosol

Before answering the following question, please watch the short video at the link: https://www.youtube.com/watch?v=klLNene_qGk&ab_channel=BunzlCleaning%26HygieneSupplies

Q19) How familiar are you with the digital technology presented in the video? (Glosair 400)?

- 1 (Could not imagine it existed)
- 2 (Did not know it existed)
- 3 (Not familiar to me)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q20) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (Do not use and have no intention to use)
- 2 (Do not use but it would be interesting to use)
- 3 (No formed idea on the subject)
- 4 (Planning to use it)
- 5 (Already using it)

Q21) Are you aware of any other similar technology that is different from the previous question? If yes, please indicate which one(s):

R: (open answer)

<u>Section 3.2: Electronic Data Recording and Monitoring Systems</u>

Before answering the following question, please watch the short video at the link: https://www.youtube.com/watch?v=Pw0biHsAQo4&ab_channel=EpimedSolutions

Q22) How familiar are you with the digital technology presented in the video? (ICU Monitor System)

- 1 (Could not imagine it existed)
- 2 (Did not know it existed)
- 3 (Not familiar to me)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q23) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (Do not use and have no intention to use)
- 2 (Do not use but it would be interesting to use)
- 3 (No formed idea on the subject)
- 4 (Planning to use it)
- 5 (Already using it)

Q24) In this question, another digital technology with the same objective is described - MONI Support. How familiar are you with it?

- 1 (Could not imagine it existed)
- 2 (Did not know it existed)

- 3 (Not familiar to me)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q25) In the hospital where you work, what is the use/intention of using this type of digital technology?
- 1 (Do not use and have no intention to use)
- 2 (Do not use but it would be interesting to use)
- 3 (No formed idea on the subject)
- 4 (Planning to use it)
- 5 (Already using it)

Q26) Are you aware of any other similar technology different from the previous questions? If yes, please indicate which one(s):
R: (open answer)

Section 3.3: Mobile Applications

Q27) Are mobile applications used in the context of Infection Control in the hospital where you work?
- Yes
- No
- Don't know
- No, to the best of my knowledge

Q28) If you answered "Yes" to the previous question, which groups of professionals use applications in the context of Infection Control in the hospital where you work? Select the options you consider true:
- Health professionals who belong to the Infection Control Committee
- Nurses
- Doctors
- Technical Assistants
- Administrators
- Other:

Q29) Do you recognize any of the following mobile applications? If yes, please select which one(s):

- Ecolab EnCompass (https://apps.apple.com/us/app/ecolab-encompass/id417674851)
Guideline Central (https://play.google.com/store/apps/details?id=com.mobiuso.IGC.guidelines&hl=en_U)
- Health Facility Guidelines Pro (https://apps.apple.com/us/app/health-facility-guidelines-pro/id453972209)
- Infection Control Pocketbook (https://apps.apple.com/us/app/infection-control-pocketbook/id525719546)
- Infection Prevention Manual (https://apps.apple.com/us/app/infection-prevention-manual/id1562661643)
- Catheter Pro (https://apps.apple.com/us/app/catheter-pro/id746425884)
- RCH Clinical Guidelines (https://play.google.com/store/apps/details?id=com.telerik.cpg&hl=en_AU)
- ESVS Clinical Guidelines (https://play.google.com/store/apps/details?id=com.esvs.clinicalPracticeGuidelines&hl=en_US)
- EVS High Touch Test (https://play.google.com/store/apps/details?id=com.simcoachgames.hightouch&hl=pt_PT&gl=US)
- EVS Patient Protector (https://play.google.com/store/apps/details?id=com.simcoach.patientprotector&hl=pt&gl=US)
MicroGuide (https://apps.apple.com/gb/app/microguide/id447171786)
- PIVM LCI_richtlijnen (https://play.google.com/store/apps/details?id=nl.rivm.lciapp&hl=en_US)

- The Chief Complaint (https://play.google.com/store/apps/details?id=app.escavo.thecc&hl=en_US)

- No

Q30) Are you aware of any other application used in infection control that is not listed in the previous question? If yes, please indicate which one(s):
R: (open answer)

Section 3.4: Electronic Systems for Hand Hygiene Monitoring

Before answering the following question, please watch the short video at the link: https://www.youtube.com/watch?v=95iPegqP0oM&ab_channel=PeterMojica

Q31) How familiar are you with the digital technology presented in the video? (Biovigil)

- 1 (Could not imagine it existed)
- 2 (Did not know it existed)
- 3 (Not familiar to me)
- 4 (Have seen it in operation)
- 5 (Have used it)

Q32) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (Do not use and have no intention to use)
- 2 (Do not use but it would be interesting to use)
- 3 (No formed idea on the subject)
- 4 (Planning to use it)
- 5 (Already using it)

Q33) In this question, other digital technologies with the same objective are described. Do you recognize any of them? If yes, please select which one(s):

- DebMed Electronic Hand Hygiene Compliance System (https://www.youtube.com/watch?v=sZw7WfulRjg&ab_channel=DebMedHealthcare)
- Droid Audio Visual Educator (DAVE) (https://www.saolta.ie/news/dave-robot-reminds-people-clean-their-hands-uhg)
- MediHandTrace (https://tracxn.com/d/companies/medihandtrace/___PTj6G8ukboUHsMCjayo5r4KoFiHC_uXZiwAodUQuRI)
- No

Q34) Are you aware of any other similar technology that is not listed in the previous question? If yes, please indicate which one(s):

R: (open answer)

Section 3.5: Real-Time Location Systems

Q35) Are Real-Time Location Systems used in the hospital where you work?

- Yes
- No
- I don't know
- No, to the best of my knowledge

Q36) In this question, some digital technologies aimed at real-time location of people or objects are listed. Do you recognize any of them? If yes, please select which one(s):

- CenTrak brand products (https://centrak.com/solutions/infection-control/hand-hygiene-compliance-monitoring)
- Secutiras Technology Products brand products (https://www.securitastechnology.com/solutions/real-time-location-systems)
- Zebra brand products (https://www.zebra.com/gb/en/solutions/industry/healthcare.html)
- Sonitor brand products (https://www.sonitor.com/products)
- No

Q37) Are you aware of any other similar technology that is not listed in the previous question? If yes, please indicate which one(s):

R: (open answer)

Q38) In the hospital where you work, what is the use/intention of using this type of digital technology?

- 1 (Do not use and have no intention to use)
- 2 (Do not use but it would be interesting to use)
- 3 (No formed idea on the subject)
- 4 (Planning to use it)
- 5 (Already using it)

Section 3.6: Artificial Intelligence -based Systems

Q39) Does the Infection Control Committee at the hospital where you work use decision support tools based on Artificial Intelligence?

- Yes

- No
- I don't know
- No, to the best of my knowledge

Q40) Do you recognize any of the following tools?

- Microsoft Power BI (https://powerbi.microsoft.com/pt-pt/)
- Google Dashboard (https://myaccount.google.com/dashboard)
- Fireflies (https://fireflies.ai/)
- Tableau (https://www.tableau.com/)
- REDCap (https://www.project-redcap.org/)
- No

Q41) Are you aware of any other similar technology that is not listed in the previous question? If yes, please indicate which one(s):
R: (open answer)

Section 4: Digital Transformation in Infection Control Strategies associated with Healthcare

Q42) According to C. Gong and V. Ribiere, Digital Transformation is defined as "A fundamental change process enabled by digital technologies with the aim of introducing improvements and radical innovations in an entity (such as an organization, a network of companies, a sector, or society) to create value for stakeholders, strategically promoting its key resources and capabilities." Based on this definition, how would you rate your knowledge of the Digital Transformation process?
- 1 (Very Insufficient)
- 2 (Insufficient)
- 3 (Sufficient)
- 4 (Good)
- 5 (Very Good)

In a healthcare organization, excluding Productivity Tools, Digital Technology-based tools can be used in two areas:

- By the Hospital, in situations of infection control and prevention associated with healthcare (e.g., Automated Disinfection Systems; Electronic Data Recording and Monitoring Systems; Applications; Electronic Hand Hygiene Monitoring Systems; Real-Time Location Systems).

- By the Infection Control Committee, in decision-making processes (e.g., AI and Machine Learning-based Systems).

Q43) In general, how do you rate the use of Digital Technologies and Digital Transformation in the hospital where you work for the prevention and control of healthcare-associated infections?

- 1 (Very Insufficient)
- 2 (Insufficient)
- 3 (Sufficient)
- 4 (Good)
- 5 (Very Good)

Q44) In general, how do you rate the use of Digital Technologies and Digital Transformation by the Infection Control Committee at the hospital where you work in the decision-making process?

- 1 (Very Insufficient)
- 2 (Insufficient)
- 3 (Sufficient)
- 4 (Good)
- 5 (Very Good)

Section 5: Perception and Attitude towards Digital Transformation

Q45) In your opinion, what role do you think Digital Technologies will play in the future of infection control in healthcare organizations?

- Irrelevant
- Not important
- Moderately important
- Very important
- Essential

Q46) In your opinion, what do you consider to be the major challenges faced by the Infection Control Committee in implementing Digital Technologies at the hospital where you work? Select the options you consider to be true:

- Lack of funding
- Lack of human resources
- Lack of technical knowledge
- Lack of time by management
- Lack of time by healthcare professionals
- Resistance from healthcare professionals
- Concerns related to privacy and data protection
- Other:

Q47) In your opinion, what do you consider to be the opportunities for improvement provided by Digital Technologies in infection control? Select the options you consider to be true:

- Better data collection and analysis
- More effective control and prevention of healthcare-associated infections
- Improved collaboration among healthcare professionals
- Increased patient satisfaction and confidence in healthcare organizations
- Health gains for patients, professionals, healthcare organizations, national healthcare service
- Increased safety in the provision of healthcare
- Other:

Q48) Do you believe that Digital Technologies are a means that can lead to an increase in the efficiency and effectiveness of infection control strategies in the hospital where you work?

- I disagree
- I somewhat agree
- I completely agree

Thanks for participating!
Any questions or clarification needed do not hesitate to contact via email mnddss1@iscte-iul.pt (Mariana Domingues)

It may be necessary to conduct interviews on this topic. If you agree to be contacted for an interview via videoconference/telephone, please leave your email address:
R: (open answer)

APPENDIX E - Variables considered to perform the statistical tests on SPSS.

Table E1: Variables considered to perform the statistical tests. Source: the author

<table>
<tr><th>VARIABLE</th><th>QUESTION ON THE QUESTIONNAIRE</th><th>ANSWER</th><th>CATEGORY</th></tr>
<tr><td rowspan="7">HR</td><td rowspan="7">Q1) To which Health Region (HR) does the hospital where you work belongs to.</td><td>Norte</td><td rowspan="2">North and Center</td></tr>
<tr><td>Centro</td></tr>
<tr><td>Alentejo</td><td rowspan="5">South and Islands</td></tr>
<tr><td>Lisboa e Vale do Tejo</td></tr>
<tr><td>Algarve</td></tr>
<tr><td>Madeira</td></tr>
<tr><td>Açores</td></tr>
<tr><td rowspan="4">Dimension</td><td rowspan="4">Q2) What is the total number of beds available at the Hospital where you work (regardless of the type of healthcare)?</td><td>< than 100 beds</td><td rowspan="2">Small-Sized</td></tr>
<tr><td>Between 100 and 200 beds</td></tr>
<tr><td>Between 200 and 500 beds</td><td rowspan="2">Large-Sized</td></tr>
<tr><td>> than 500 beds</td></tr>
<tr><td rowspan="2">University/Non-University</td><td rowspan="2">Q4) Is it a University Hospital?</td><td>University</td><td>University Hospital</td></tr>
<tr><td>Non-University</td><td>Non-University Hospital</td></tr>
<tr><td rowspan="2">Knowledge on Productivity Tools</td><td>Q7) In this question, productivity tools are listed. How familiar are you with them?</td><td>3 (I feel minimally familiar with the tool and use it occasionally) or higher in at least 11 of the 23 Productivity Tools presented</td><td rowspan="2">Reasonable Knowledge on productivity tools used by ICCs</td></tr>
<tr><td>Q9) How would you rate the general level of productivity tool usage by the ICC of the hospital where you work?</td><td>Sufficient or higher</td></tr>
<tr><td rowspan="7">Familiarity on digital technologies used in Infection Control</td><td>Q11) How familiar are you with the digital technology presented in the video? (Tru-D SmartUVC)</td><td rowspan="7">4 (Have seen it in operation) or higher on</td><td rowspan="7">Familiarity with digital technologies used in infection control
(when at least 3 of the 6 previous criteria were met)</td></tr>
<tr><td>Q15) How familiar are you with the digital technology presented in the video? (Steris VHP systems)</td></tr>
<tr><td>Q19) How familiar are you with the digital technology presented in the video? (Glosair 400)?</td></tr>
<tr><td>Q22) How familiar are you with the digital technology presented in the video? (ICU Monitor System)</td></tr>
<tr><td>Q24) How familiar are you with the digital technology presented in the video? (MONI Suport)</td></tr>
<tr><td>Q31) How familiar are you with the digital technology presented in the video? (Biovigil)</td></tr>
<tr><td>Q11) How familiar are you with the digital technology presented in the video? (Tru-D SmartUVC)</td></tr>
<tr><td rowspan="3">Use/Intention to use digital technologies in Infection Control</td><td>Q12) In the hospital where you work, what is the use/intention of using this type of digital technology?</td><td rowspan="3">4 (I am planning to use it)</td><td rowspan="3">Positive use/intention to use digital technologies in Infection Control context
(when at least 4 of the 10 previous criteria were met)</td></tr>
<tr><td>Q16) In the hospital where you work, what is the use/intention of using this type of digital technology?</td></tr>
<tr><td>Q20) In the hospital where you work, what is the use/intention of using this type of digital technology?</td></tr>
</table>

	Q23) In the hospital where you work, what is the use/intention of using this type of digital technology?		
	Q25) In the hospital where you work, what is the use/intention of using this type of digital technology?		
	Q27) Are mobile applications used in the context of Infection Control in the hospital where you work?	Yes	
	Q32) In the hospital where you work, what is the use/intention of using this type of digital technology?	4 (I am planning to use it)	
	Q35) Are Real-Time Location Systems used in the hospital where you work?	Yes	
	Q38) In the hospital where you work, what is the use/intention of using this type of digital technology?	4 (I am planning to use it)	
	Q39) Does the ICC at the hospital where you work use decision support tools based on Artificial Intelligence and Machine Learning?	Yes	
Knowledge on digital transformation and digital technologies	Q42) According to C. Gong and V. Ribiere, Digital Transformation is defined as "(…)" Based on this definition, how would you rate your knowledge of the Digital Transformation process?	Sufficient or higher	Reasonable knowledge on digital transformation and digital technologies (when two out of the three criteria were met)
	Q43) In general, how do you rate the use of Digital Technologies and Digital Transformation in the hospital where you work for the prevention and control of healthcare-associated infections?	Sufficient or higher	
	Q44) In general, how do you rate the use of Digital Technologies and Digital Transformation by the ICC at the hospital where you work in the decision-making process?	Sufficient or higher	

APPENDIX F – Convergency tables between the variables described on Table 2.

Table F1: Knowledge of productivity tools according to the HR to which the hospital belongs.

HR	Knowledge on Productivity Tools					
	Yes			No		
	n	% relative to RHA	% relative to total	n	% relative to RHA	% relative to total
Norte	7	70,0	20,6	3	30,0	8,8
Centro	5	71,4	14,7	2	28,6	5,9
Alentejo	0	0,0	0,0	1	100,0	2,9
Lisboa e Vale do Tejo	8	66,7	23,5	4	33,3	11,8
Algarve	1	100,0	2,9	0	0,0	0,0
Madeira	1	100,0	2,9	0	0,0	0,0
Açores	1	50,0	2,9	1	50,0	2,9
Total	23		67,6	11		32,4

Table F2: Knowledge of productivity tools according to the hospitals dimension.

Dimension	Knowledge on Productivity Tools					
	Yes			No		
	n	% relative to dimension category	% relative to total	n	% relative to dimension category	% relative to total
Small-sized	4	57,1	11,8	3	42,9	8,8
Large-sized	19	70,4	55,9	8	29,6	23,5
Total	23		67,6	11		32,4

Table F3: Knowledge of productivity tools according to the hospitals category.

Hospital Category	Knowledge on Productivity Tools					
	Yes			No		
	n	% relative to hospital category	% relative to total	n	% relative to hospital category	% relative to total
University	8	72,7	23,5	3	27,3	8,8
Non-University	15	65,2	44,1	8	34,8	23,5
Total	23		67,6	11		32,4

Table F4: Familiarity on Digital Technologies used in infection control according to the HR to which the hospital belongs.

HR	Familiarity on Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to RHA	% relative to total	n	% relative to RHA	% relative to total
Norte	0	0,0	0,0	10	100,0	29,4
Centro	3	42,9	8,8	4	57,1	11,8
Alentejo	0	0,0	0,0	1	100,0	2,9
Lisboa e Vale do Tejo	5	41,7	14,7	7	58,3	20,6
Algarve	1	100,0	2,9	0	0,0	0,0
Madeira	1	100,0	2,9	0	0,0	0,0
Açores	0	0,0	0,0	2	100,0	5,9
Total	10		29,4	24		70,6

Table F3: Familiarity on Digital Technologies used in infection control according to the dimension of the hospital.

Dimension	Familiarity on Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to dimension category	% relative to total	n	% relative to dimension category	% relative to total
Small-sized	2	28,6	5,9	5	71,4	14,7
Large-sized	8	29,6	23,5	19	70,4	55,9
Total	10		29,4	24		70,6

Table F4: Familiarity on Digital Technologies used in infection control according to the hospitals category.

Hospital Category	Familiarity on Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to hospital category	% relative to total	n	% relative to hospital category	% relative to total
University	4	36,4	11,8	7	63,6	20,6
Non-University	6	26,1	17,6	17	73,9	50,0
Total	10		29,4	24		70,6

Table F5: Use/Intention to use Digital Technologies in infection control according to the HR to which the hospital belongs.

HR	Use/Intention to use Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to RHA	% relative to total	n	% relative to RHA	% relative to total
Norte	3	30,0	8,8	7	70,0	20,6
Centro	1	14,3	2,9	6	85,7	17,6
Alentejo	0	0,0	0,0	1	100,0	2,9
Lisboa e Vale do Tejo	3	25,0	8,8	9	75,0	26,5
Algarve	0	0,0	0,0	1	100,0	2,9
Madeira	0	0,0	0,0	1	100,0	2,9
Açores	0	0,0	0,0	2	100,0	5,9
Total	7		20,6	27		79,4

Table F6: Use/Intention to use Digital Technologies in infection control according to the hospitals dimension.

Dimension	Use/Intention to use Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to dimension category	% relative to total	n	% relative to dimension category	% relative to total
Small-sized	1	14,3	2,9	6	85,7	17,6
Large-sized	6	22,2	17,6	21	77,8	61,8
Total	7		20,6	27		79,4

Table F7: Use/Intention to use Digital Technologies in infection control according to the hospitals category.

Hospital Category	Use/Intention to use Digital Technologies used in Infection Control					
	Yes			No		
	n	% relative to hospital category	% relative to total	n	% relative to hospital category	% relative to total
University	1	9,1	2,9	10	90,9	29,4
Non-University	6	26,1	17,6	17	73,9	50,0
Total	7		20,6	27		79,4

Table F8: Knowledge on Digital Transformation and Digital Technologies according to the HR to which the hospital belongs.

HR	Knowledge on Digital Transformation and Digital Technologies					
	Yes			No		
	n	% relative to RHA	% relative to total	n	% relative to RHA	% relative to total
Norte	1	10,0	2,9	9	90,0	26,5
Centro	2	28,6	5,9	5	71,4	14,7
Alentejo	0	0,0	0,0	1	100,0	2,9
Lisboa e Vale do Tejo	4	33,3	11,8	8	66,7	23,5
Algarve	0	0,0	0,0	1	100,0	2,9
Madeira	0	0,0	0,0	1	100,0	2,9
Açores	0	0,0	0,0	2	100,0	5,9
Total	7		20,6	27		79,4

Table F9: Knowledge on Digital Transformation and Digital Technologies according to the hospitals dimension.

Dimension	Knowledge on Digital Transformation and Digital Technologies					
	Yes			No		
	n	% relative to dimension category	% relative to total	n	% relative to dimension category	% relative to total
Small-sized	2	28,6	5,9	5	71,4	14,7
Large-sized	5	18,5	14,7	22	81,5	64,7
Total	7		20,6	27		79,4

Table F10: Knowledge on Digital Transformation and Digital Technologies according to the hospitals category.

Hospital Category	Knowledge on Digital Transformation and Digital Technologies					
	Yes			No		
	n	% relative to hospital category	% relative to total	n	% relative to hospital category	% relative to total
University	1	9,1	2,9	10	90,9	29,4
Non-University	6	26,1	17,6	17	73,9	50,0
Total	7		20,6	27		79,4