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A STUDY OF THE INTERNET OF THINGS AND RFID TECHNOLOGY: BIG DATA IN NAVY MEDICINE

December 2017

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The Internet of things (IoT) and big data describe the movement of many industries toward a focus on data collection, communication and analysis. Tools such as radio frequency identification (RFID) are leveraged in order to maximize the potential benefits gained from the IoT and big data, connecting devices to one another and providing end users meaningful ways to interact with technology. The healthcare industry has revolutionized its approach to the IoT, with hopes of realizing cost savings, increasing efficiencies and improving quality of care. Navy medicine has a history of big data initiatives, and in the future could include even more intersection between technology and healthcare. In the adoption of new technologies, resistance to technology change is a possibility. The type and strength of resistance and its mediation is largely dependent on how leaders approach resistance and acceptance among end users. The introduction of new RFID technologies has the potential to positively impact processes such as surgical tool sterilization and patient and employee tracking. Moving into the future, the integration between healthcare and technology continues to develop at a rapid pace, and the IoT, big data and RFID technology should play an important role in the healthcare industry.

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A STUDY OF THE INTERNET OF THINGS AND RFID TECHNOLOGY: BIG DATA IN NAVY MEDICINE

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LIST OF ACRONYMS AND ABBREVIATIONS

CHAMPS	Career History and Archival Medical and Personnel System
CIS	Computer Information System
DOD	Department of Defense
DMLSS	Defense Medical Logistics Support System
EHR	Electronic Health Record
HIMSS	Healthcare Information and Management Systems Society
HIT	Health Information Technology
IoT	Internet of Things
IT	Information Technology
MHS	Military Health System
NMLC	Naval Medical Logistics Command
NPS	Naval Postgraduate School
RFID	Radio Frequency Identification
RSB	Retained Surgical Body

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I. INTRODUCTION

A. BACKGROUND

The healthcare industry has rapidly transformed since the turn of the century. Many processes completed by hand, paper, over the phone or via fax have been streamlined and integrated with evolving technologies, allowing for the ability to collect, retain and analyze data on a scale previously unimagined (Cnossen et al., 2015; Patrick, 2016; Fracalossi et al., 2010). The Internet of things (IoT), a central topic to this study, is described as a network of objects connected via the Internet, collecting and sharing information via embedded sensors (Aydin, Çelik, & Demirer, 2017; Olson, 2016). From 2015 to 2017, the number of devices (in billions) grew from 15.41 to 20.35, and by 2025 that number is predicted to grow to 75.4 (Statista, n.d.). Big data is described as the collection of data utilized to transform business processes and realize competitive advantages, with emphasis on volume, velocity and variety (Brynjolfsson & McAfee 2012; Anthony, Kung, Ting, & Wang, 2015). A technology that has been slow to see adoption within the healthcare field, but has enabled the IoT and big data collection in many other industries is radio frequency identification (RFID) technology (Caoustasse, Cunningham, Deslich, Meadows, & Willson 2015; Chen & Jin, 2012). This paper poses that the intersection of the IoT, big data and RFID technology within the medical field is an important area of research, as it is still largely untapped in terms of real-world application.

A major driver for RFID innovation has been to manage costs and increase efficiency (Roy & Veronneau, 2009; Conklin et al., 2009). Organizations could also pursue RFID technology as “it may improve cost by increasing capacity, reducing cycle time, enabling self-service or automating value-adding processes.” (Apte, Dew, & Ferrer, 2009, p. 417). In recent years national medical costs have risen across the board, witnessed in programs such as Medicare and Medicaid, as well as in individual cost areas such as hospital, physician and pharmaceutical expenditures (Centers for Medicare and Medicaid Services, 2017). Access to care and usage has risen as well, partly as a function of the extended coverage offered to more of the population under the Affordable Care Act (Centers for Disease Control and Prevention, 2016; Centers for Medicare and Medicaid

Services, 2017). National healthcare expenditures reached a new all-time high of $3.35 trillion in 2015, driven largely by a growing economy, rapid growth in medical prices and the growth in aging populations (Alonso-Zaldivar, 2016). The widespread creation of an IoT could bring benefits within data collection and analysis, as well as potential future cost savings (Patel, 2017). In order to control these rising costs, leaders in both military and civilian healthcare have sought out new forms of innovation in areas such as RFID technology in order to maximize the benefits of the IoT and big data (Lee & Davies, 2013).

RFID technology naturally lends itself to the structure of the IoT (Chen & Jin, 2012). RFID technology typically comes in the form of tags, or other small devices designed to communicate location data via an antenna to a sensor located nearby, and can be either active, or passive (Want, 2006). Active tags are powered by an internal battery, and capable of transmitting real-time data at any given time, whereas passive tags require a reader device, typically a handheld scanner, to provide a power source via an electromagnetic wave inducing a current (Want, 2006). In Figure 1, the basic process of RFID tag data collection and transmission is shown for active and passive tags is shown, the key difference being the passive tags requirement to be within the near field, being powered to transmit its data (Kolarvoski, Tengler, & Vaculík, 2013).

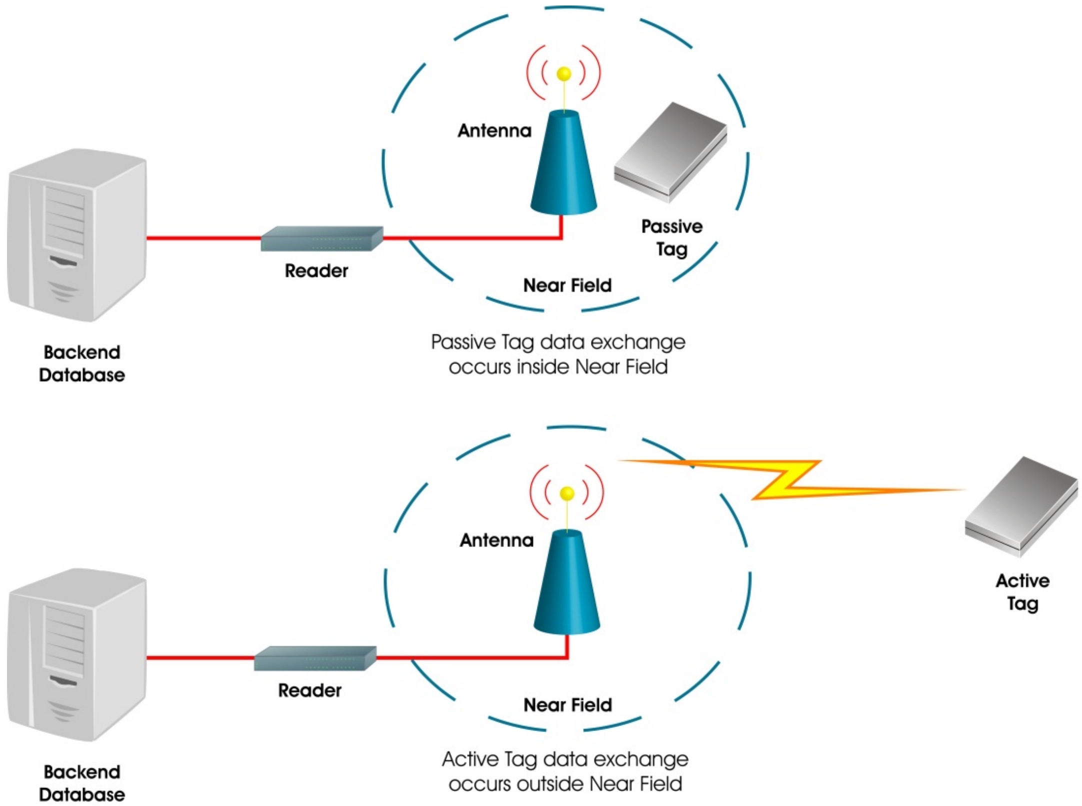

Figure 1. Passive and Active Tag Processes. Source: Kolarovszki, Tengler, and Vaculík (2013).

Typically passive tags are less costly, but the benefits of active tags continual tracking as well as the decreased workload involved in data collection make the implementation of both beneficial dependent on the situation and requirements of the technology (Caoustasse et al., 2015; Roy & Vernneau, 2009). Figure 2 shows a sample of a mobile RFID reader and basic tag.

Figure 2. RFID Starter Kit (Mobile). Source: Snively (2017).

As with any developing technology, RFID has faced challenges. Miles, Sarmae, and Williams (2008) provided the challenges discussed by Under Secretary of Commerce for Technology Robert Cresanti in 2007 at the European Union RFID Forum as, “standards and interoperability issues across various RFID systems, companies and countries, and privacy and security concerns” (p. xv). Understanding the challenges related to the specific technological components of RFID technology is a field of study future Navy medicine research with more specific product application should consult. Given the depth and range of challenges facing each individual compenent of RFID technology it was not discussed in this paper (Simplot-Ryl & Stojmenovics, 2010). Over the course of this technologies maturation, Navy medicine has invested in and benefited from multiple Naval Postgraduate School (NPS) and Naval Medical Logistics Command (NMLC) projects regarding the implementation of RFID technology, its potential costs and benefits and studies in regards to the technology functions and capabilities (Chávez, Nixon, & Sánchez, 2014; Macalanda, 2006; Olson, 2015). The many studies and projects conducted at NPS and NMLC provide Navy medicine and analytics teams important data on the successes and the challenges of widespread implementation of RFID. That being said RFID technology may have more uses that currently are not being considered for implementation. These uses could house the potential for further creation of an IoT within hospitals, particularly devices communicating information between people as well as other machines and software systems.

B. PROBLEM STATEMENT

NMLC conducts cost benefit analyses regarding technology and innovation in Navy medicine, but as RFID technology matures and the cost barriers to entry decrease, future trend analysis is becoming a more important part of that discussion with regards to RFID technology. Three main questions are considered in this study: What is the current posture of Navy medicine with regards to the development and wide spread deployment of the IoT and big data? Given the future needs of the Navy, how should Navy medicine posture itself with regards to the IoT and dig data? What steps should Navy medicine take to prepare for the future? These three questions guide this investigation into IoT and big data innovation and provide a brief review of Navy medicine efforts to date.

C. LITERATURE REVIEW

Identifying major trends in regards to the IoT, big data and RFID as well as the factors that influence the feasibility of technology implementation are the end-goals of this project. To this end, an extensive literature review into the development of the IoT, big data and how RFID enables such endeavors. Current uses of RFID to support the IoT and big data collection are reviewed. Particular emphasis is being placed on the factors influencing adoption of the technology which supports the IoT and big data collection. This I in order to identify common characteristics and conduct an analysis on similarities or non-similarities to the medical field and Navy medicine. The literature constituting the framework for the research conducting stage is important, considering the theoretical approach to this study, and the lack of pre-existing empirical data (Watson & Webster, 2002). In Pautasso's (2013) discussion on literature review, several of the points of emphasis are picked out as particularly relevant to this study;

- "Define a topic and audience" (p. 1)
- "Search and re-search the literature" (p. 1)
- "Choose the type of review you wish to write" (p. 2)
- "Find a logical structure were identified" (p. 3)

The topic being the IoT, RFID technology and big data within Navy medicine, the audience being Navy medicine leadership and research teams, the rapid review constituting the search and type of review, and the structure following the past, current and future of Navy medicine with regards to the topic of study (Pautasso, 2013). Rapid reviews of literature are typically conducted over the course of months rather than years, and consist of clear objectives, defined criteria for studies, an assessment of the validity of findings, and a discussion of the characteristics of findings (Dryden et al., 2015). Research into the conceptual definitions, domain limitations, relationship-building and predictions are important parts this projects rapid review of literature (Wacker, 1998). For this study, research sources focus on google scholar to assess the validity of potential sources, and through the Naval Postgraduate School Library database and archive. Possible sources and guidance for research being provided by lead advisor Dr. Simon Veronneau and co-advisor Dr. Geraldo Ferrer. Current and historical research is also an important source to utilize, following the past-present-future chapter structure (Pautasso, 2013). While the initial goals of the project included a more broad approach to analyzing RFID technologies impact on the healthcare industry, the research has been ultimately reframed around the central idea of building a smart hospital as this has helped to narrow the focus of the topic and provided meaningful search results into the IoT, big data and RFID technology (Guinard & Fuhrer, 2006).

The rapid review of literature is the means by which research is conducted on the IoT, big data and RFID; naturally theory building structure fits as a means to test and evaluate the research collected (Ciliska, Ganann, & Thomas, 2010; Cushman, Grimshaw, Khangura, Konnyu, & Moher, 2012). Necessary to theory building is the identification of the unit of analysis, in this case Navy medicine (Koeglreiter, Smith, & Torlina, 2012). Theory building requires conceptual definitions, domain limitations, relationship-building and predictions (Wacker, 1998). Conceptual definitions of the IoT, big data and RFID technology are explored and reaffirmed during the research portion of this study. Although research is conducted broadly within the civilian healthcare industry, the domain of application is limited to Navy medicine within the confines of a fiscally uncertainty, as this is the likely scenario for the foreseeable future. The process of relationship-building and prediction occurs naturally in this study, as lessons learned and predictions of theory are identifiable within civilian literature (Wacker, 1998). The theory building model takes a cyclical approach to the analysis of research and application of predictions (Carlile & Christensen, 2004). The first part of theory building includes observation, categorization and statements of association resulting in a comprehensive understanding of the past, current and future potential for IoT, big data and RFID usage within the healthcare field as a whole was achieved (Lynham, 2002). If done properly, the research should confirm general trends and ideas. The second portion of theory building involved predictions applied to a scenario or case (Lynham, 2002). These predictions then being tested against Navy medicine as an organization, particularly within the study of resistance to change and scenario analysis of the degree and type of technology integration into healthcare. The cyclical nature of this methodology and its predictive nature lends itself well to studying the intersection of technology and Navy medicine, as past research into the IoT, big data and RFID technology and its usefulness for Navy medicine is limited, leaving a gap in research to be addressed. Limitations concerning the additional mission and capability requirements of Navy medicine and the deployability of technology and personnel did impacted research. That being said, the similarities between civilian and Navy medicine healthcare in terms of industry standards and generally accepted procedures and views regarding the usefulness of technology will facilitate the gathering and applying of research gained from the civilian healthcare industry.

D. THESIS OUTLINE

Chapter II of this master of business administration research project reviews literature discussing the background of the IoT, big data and RFID in Navy medicine and the healthcare industry. Chapter III looks at the future of medicine, particularly in regards to creating an IoT within healthcare organizations, and trends in RFID technology, which are relevant to organizations positioning themselves for the future. Chapter IV discusses how Navy medicine can best position itself for future innovations. Chapter V provides a summary, limitations, conclusions, as well as recommendations for future studies with regards to pursuing an IoT within healthcare, and RFID technology.

II. NAVY MEDICINE CURRENT STATUS: IOT AND BIG DATA

A. NAVY REQUIREMENTS

The mission of Navy medicine has stayed relatively consistent over the years, "Keep the Navy and Marine Corps family ready, healthy and on the job" (Navy Medicine, 2017, Para. 3). That being said, the methods by which it accomplishes that mission continue to evolve. Understanding the requirements of Navy medicine and its logistics component NMLC is an important step in identifying the strengths and weaknesses of an organization. In recent years, the Department of Defense (DOD) as a whole has made audit readiness and preparation a priority, testing acquisition, equipment and supply management systems for weaknesses and fixing vulnerabilities (Under Secretary of Defense Comptroller, 2017). Navy medicine continues to demonstrate its commitment to creating a fiscally transparent and audit ready medical support force, as evidenced by winning 7 out of the 28 Assistant Secretary of the Navy Financial and Comptroller Awards (Felipe, 2016). Unfortunately, as a whole the DOD still completes many processes manually, resulting in a failure to find "viable, long-term solution to audit, and put substantial demands on limited resources while failing to address underlying root causes of audit deficiencies (Under Secretary of Defense Comptroller, 2017, p. 14). Going into the future, this study poses that further initiatives into the IoT, big data and RFID technologies are crucial in preparing for future audits in a timely manner (Sari, 2010).

Even with a renewed emphasis audit readiness, the importance of providing unmatched quality of care continues to be a focus of Navy medicine and of the Surgeon General Vice Admiral Faison (Wise, 2016). In the 2016 strategic priorities announcement made by the surgeon general, several key factors are identified as important for the future of Navy medicine. The surgeon general emphasizes three main pillars for success within the enterprise; readiness, health and partnerships (Wise, 2016). What finding success in these three pillars means is a constantly moving target, and as Vice Admiral Faison points out, change continues to be a constant. Chapter II looks at past and current measures targeting aspects those pillars, and Chapters III & IV discusses the future technological trends such as IoT and big data through RFID, and the success and challenges they may face.

At the conclusion of Vice Admiral Faison's remarks, he makes the important point that you cannot look at Navy medicine through the civilian institution lens (Wise, 2016). A large-scale enterprise such as Navy medicine requires technologies that are similar across the enterprise, capable of being leveraged in multiple hospitals encompassing different scopes of care. Active duty deployment duty station turnover is also a concern, necessitating the widespread adoption of similar technologies to ease these burdens as staff adjusts to new command and hospital operations (Wise, 2016). These are important factors when considering which literature to emphasize, as studying literature focused on civilian innovation is a great way to find ways to better an organization, but not always will they be readily adaptable to a military hospital and its unique requirements.

B. PAST INNOVATIONS

Military Medicine is no stranger to big data collection. In order to better manage its military, veteran and dependent population, Navy medicine invests in many information technology (IT) initiatives. This is accomplished through organizations such as the Navy Medical Information Management and Information Technology Support Organization, with a stated mission of "Providing information systems products and services to Navy medicine" (Coffey, 2008, Para. 5). It is also supported by M-6 Information Management and Technology which "Provides leadership and oversight in the areas of IM/IT governance, architecture, information assurance, privacy, workforce, training, and Information integration" (Navy Medicine, 2017, Para. 1).

In the December 2001 Population Health Improvement Plan and Guide, the future of population health improvement measures for the DOD are laid out (DOD TRICARE Management Activity, 2001). The plan still holds true as measures for what would now be considered big data and the IoT. Although in 2001 existing technology and the way data was collected was much different from today, the understanding was that the future would most likely require heavy investments in technology, as data collection and observation methods would change (DOD TRICARE Management Activity, 2001). The Population

Health Improvement Plan and Guide goes on to describe the complexity of planning and programming for the Military Health System (MHS). Particular attention is paid to meeting the increasing technology needs, service costs and demands being placed on the enterprise. The document discusses the importance of embracing the rapid advancement of IT, and the importance of harnessing the wealth of health information becoming more accessible (DOD TRICARE Management Activity, 2001). Ultimately, by pushing MHS and DOD to adopt these technology innovations, Navy medicine positions itself to increase enterprise-wide understanding of population health with potential for quality improvements and cost reductions (DOD TRICARE Management Activity, 2001).

Another example of big data management in Navy medicine is the Career History and Archival Medical and Personnel System (CHAMPS). CHAMPS is an older system which stores over 10 million service members' personal and medical data from entry in the military to discharge. It is a useful tool in terms of analyzing big data across the enterprise (Galarneau, 2016). Scientists and researchers at the Naval Health Research Center pour over current and historical data, with the goals of identifying trends which could help result in better care being provided, and cost savings in the future (Galarneau, 2016). Although many of the methods of capturing the historical data in the database did not utilize IoT integrated devices, going into the future systems likes CHAMPS could see increased population with data via the use of IoT connected devices and increase in automated data collection.

In 2005 Naval Medical Center San Diego introduced a Mass Casualty tracking program utilizing RFID technology and software (Fry & Lenert, 2005). The MASCAL software and hardware system used active RFID tags to track patients, equipment and staff during disaster response situations as well as providing data from personnel databases, medical information systems, and registration applications to manage chaotic situations (Fry & Lenert, 2005). MASCAL operated with a hospital command center and local area managers to manage processes and patient throughput during MASCAL situations. MASCAL was designed to help allocate resources based on patient flow bottlenecks, impacting areas such as; stabilization &transport, turnover, registration, workup and disposition. The system required a backup in case of network failure, allowing for contingency capabilities (Fry & Lenert, 2005).

C. CURRENT INNOVATIONS

Recently, there has been a push to introduce more telemedicine technologies into Navy medicine (Perron, 2014). Telehealth technologies can include telephones, email, remote patient monitoring devices as well as online platforms through which doctors and patients communicate to manage their health (Medicaid, n.d.). The electronic health record (EHR) falls into the category of telemedicine, with improvements in areas such as; quality and convenience of patient care, patient participation in care, accuracy of diagnoses and health outcomes, care coordination, practice efficiencies and cost savings (Newhook, 2014; Health IT, 2014). The EHR also gives patients the ability to be more informed about their own care, and actively participate in their own health (Health IT, 2014).

Although the DOD has utilized EHR innovations for some time, the MHS recently rolled out a new EHR, the MHS Genesis. MHS Genesis is designed to facilitate a team approach to medicine, better allow for the use of cutting-edge technology and to be leveraged worldwide for service members, veterans and their families (Cronk, 2017). Along with the development of MHS Genesis, the next step in maximizing the capabilities of EHRs for Navy medicine has been introducing Relay Health, an Internet platform connecting patients to their medical team (Naval Hospital Pensacola, n.d.). Naval Hospital Pensacola (n.d.) states that Relay Health is designed so that patients have the ability to:

- "Communicate securely with your Medical Homeport Team" (Para. 4)
- "Request a prescription refill" (Para. 4)
- "Receive lab or other diagnostic test results" (Para. 4)
- "Access health education information" (Para. 4)
- "Set up and management of Personal Health Records (PHR)" (Para. 4)

This paper poses that CHAMPS as well as MHS Genesis and its predecessors help to develop an IoT within Navy medicine through facilitating the collection and analysis of big data. To this researcher's knowledge, initiatives such as these do not included the widespread use of RFID technology. Rather they are limited to initiatives such as in 2003 when Navy medicine implemented RFID technology to track patients in forward deployed hospitals, ensuring their treatment was coordinated amidst the chaotic nature of forward deployed emergency health situations (Yoshida, 2003). In the realm of RFID technology, Navy medicine is in the beginning stages of pursuing enterprise wide RFID innovation, namely through the recent Navy medicine roll out the Two-Bin Kanban System and limited studies into RFID technology for equipment management (Chávez, et al., 2014; Macalanda, 2006; Olson, 2015). The Kanban system helps to better manage consumable supply, and utilizes RFID tags to notify supply personnel when to reorder supplies in departments throughout the hospital. RFID research previously completed helps to understand the potential for better management of command equipment, increasing accountability of assets and ensuring annual maintenance is performed (Chávez, et al., 2014; Macalanda, 2006; Olson, 2015).

Legacy technology challenges described by Reddy S. B. & Reddy R. (2002) in *Competitive agility and the challenge of legacy information systems* are still relevant today, as the integration of new technologies with aging legacy information systems remains a difficult task. From personal experience, a legacy system which has its fair share of problems being incorporated with new technologies is the Defense Medical Logistics Support System (DMLSS). DMLSS is a software platform facilitating acquisition and equipment management programs via ordering medical supplies, just-in-time logistics and medical equipment maintenance (Military Health System, n.d.). In the past, it has reduced the amount of time healthcare providers spend on logistics planning and management and facilitated improvements in effectiveness, efficiency and quality of care provided. It also ensures the DOD meets Federal Drug Administration, Federal Information Security Management Act, Federal Financial Management Improvement Act and Joint Commission requirements (Military Health System, n.d.) Unfortunately, when DMLSS was originally designed in the 90's, there was no way the software designers could have predicted the rapid advancement of technology and the new requirements and capabilities which it would be required to leverage and operate with (Darling, 2003). Although at one time these systems were cutting edge, the difficulties of managing legacy technology such as DMLSS have become apparent in several recent Navy medicine RFID technology initiatives. In Navy medicine's Kanban initiative, DMLSS software limitations and initial design purpose incompatibility have resulted in limitations on the maximum benefits of the Kanban System Olson, 2015). Going forward, acquisition and IT leadership should make clear strategy decisions in terms of legacy systems and investments into future to maximize benefits and minimize future costs for Navy medicine.

D. IMPACTS OF THE CURRENT CULTURE

Understanding the culture of the medical field as a whole, and specifically Navy medicine is important in identifying potential challenges to the growth of the IoT and big data collection, in particular through the use of RFID technology. Botterman, Oranje-Nassau, Schindller, and Vilamovska (2012) reported in *Policy Options for Radio Frequency Identification (RFID) Application in Healthcare; a Prospective View* on the implementation of RFID technology within healthcare organizations and its dependence on the values of the culture it is based within. Some cultures place a higher value on reducing operating costs when identifying potential innovations for implementation, with the United States falling very much into this category, particularly as it struggles to manage rising healthcare costs and an aging population, seeks to reduce operating costs Botterman, Oranje-Nassau, Schindller, & Vilamovska (2012). The need to seek profit-driven efficiencies spurs much of the RFID development in the US, while in Europe interest in RFID technology concerns quality of care, as evidenced on the broader approach to access to healthcare (Botterman et al., 2012).

Interestingly, it could be argued that Navy medicine's reason for adoption of RFID technology falls in the middle of this spectrum, balancing quality with cost. The services Navy medicine provide directly impact the warfighter and their ability to complete their assigned missions, therefore the quality of care cannot afford to be diminished (Wise, 2016). At the same time, as the healthcare provided is directly funded by taxpayer dollars, it is necessary that cost remain a factor. This balance requires a unique outlook on care, particularly regarding innovation. One of the key components of NMLC is excellence, and this excellence is described as a continued process, improving and attuning the organization to customer needs, using innovative ideas and not relying on past achievements (Naval Medical Logistics Command, n.d.).

IT can also be seen as a double edged sword, that it can improve productivity, quality and efficiency, but that it also is difficult to tie these positive outcomes directly to Health Information Technology (HIT) initiatives (Lapointe, Mignerat, & Vedel, 2010). Industries emphasis on positive results can misconstrue measures of productivity regarding IT, with four types being identified in particular; measurement error, time lag, redistribution of profit and mismanagement of IT (Lapointe et al., 2010). Understanding healthcare professionals, administrators and patients priorities through the HIT Impacts Assessment Framework in Figure 3 can help leadership to define and communicate positive results and manage expectations during the deployment of new technologies (Lapointe et al., 2010).

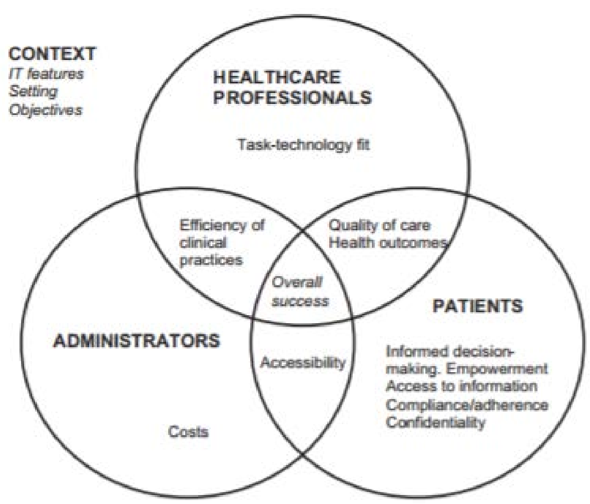

Figure 3. HIT Impacts Assessment Framework. Source Lapointe, Mignerat, and Vedel (2010).

The way RFID technology is currently applied is also an important aspect to discuss regarding the culture of medical logistics, specifically how it is used to address problems. Currently, applications of RFID technology are very specific (Botterman et al., 2012). Individual problems arise and managers seek individual solutions to those problems. Although there are many proponents for widespread RFID roll-outs, there is currently a very fractured network with little wide spread IT systems. What does this mean for medicine? It underlies the importance of addressing how we view problem solving and solutions. In the past, as technology rapidly evolved, problems were identified in vacuums and solutions were devised for those single problems. As technology has advanced we see that in many cases problems once viewed as unique in fact have solutions which could be leveraged across multiple platforms for multiple problems (Botterman et al., 2012).

E. CURRENT LIMITATIONS OF RFID TECHNOLOGY

Although RFID technology has a multitude of potential benefits, the technology is not without its limitations and areas of concern which are hurdles for widespread RFID adoption, and a barrier to its integration into the IoT and big data collection and analysis (Egri, Ilie-Zudor, Kemény, & Monostori, 2006). Current issues and limitations of RFID technology include; standardization, cost, faulty tags, quick technology obsolescence, adverse environment conditions, security and privacy issues and the potential for virus attacks and hacking (Egri et al. 2006). Standardization is an issue for Navy medicine, as most technology rollouts would be enterprise wide, and therefore need to be compatible at all of Navy medicines unique medical treatment facilities as seen in previous studies (Chávez, et al., 2014; Macalanda, 2006; Olson, 2015). The cost factor is also prohibitive in implementing future Navy medicine technology innovations, as well as the competing nature of the acquisition and resource management process. Although the technology brings to the IoT and big data collection, for such a project to be successful it needs to be rolled out across the enterprise. This requires allocation of limited resources, and competition against other projects seeking funding to meet logistics needs of Navy medicine. The necessity of providing value for taxpayer dollars is also a constant benchmark for any innovation within the military. The value of taxpayer dollar resources cannot be understated, hence initiatives in Navy medicine must be designed to succeed with little risk of failure. With limited competing resources, and a duty to remain answerable to the taxpayer, experimenting in RFID technology remains a risky investment, and only now with more widespread civilian adoption across industries is this technology beginning to be viewed with more potential. As more hospitals adopt RFID technology, and industry leaders view it more as an industry standard, the limitations and issues surrounding RFID technology could naturally be less of a hurdle for its adoption.

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III. FUTURE OF THE IOT, BIG DATA AND RFID IN MEDICINE

A. NAVY MEDICINE: FUTURE REQUIREMENTS

As detailed in Chapter II, the surgeon general lays out the guiding principles for the future of Navy medicine (Wise, 2016). The rapid evolution of technology coupled with the continued necessity of easily deployable healthcare solutions in support of the warfighter necessitate further integration of the IoT, RFID technology and other IT solutions into Navy medicine. With continued budget uncertainty and the necessity of doing more with less, the integration of smart hospitals and IoT technology to increase efficiencies becomes increasingly important for Navy medicine as it strives to deliver successful patient outcomes and to understand and promote positive population health trends.

B. SMART HOSPITALS

Hospitals seem to naturally adapt a high level of technology integration as technology evolves, particularly in response to the development of medical procedures and their growing dependence on technology. The pursuit of big data and the implementation of the IoT and RFID technologies spurs the development of facilities becoming known as smart hospitals (Guinard & Fuhrer, 2006). A smart hospital is a facility designed from its core to centralize its operations around the collection of data and leveraging it to promote efficiency, positive patient outcomes and to leverage big data in as many areas as possible (Tayler, 2017). In the past, mainly large organizations such as Navy medicine collected and analyzed big data to manage population health and increase hospital efficiencies across the enterprise. But with healthcare utilization and costs increasing, individual hospitals within larger hospital networks are increasingly being enticed into developing the smart hospital model to increase efficiency, patient satisfaction and manage rising costs associated with day to day operations (Texas Health, 2014; Swedberg, 2014).

An example of the smart hospital which manages such routine operations with RFID technology is the Texas Health Harris Methodist Hospital Alliance of Fort Worth, TX built in 2012 (Swedberg, 2014). This hospital employs a real-time location system using Centrak Gen2IR tags and readers, tracking patients (wrist bands), employees (employee badges) and high value assets (Swedberg, 2014). The tags help locate assets quickly, improve the discharge process, enable family and friends to quickly locate their loved ones in the hospital, and helps the hospital track which personnel may have come into contact with specific patients during infectious disease control events (Swedberg, 2014). The hospital has been awarded accolades from numerous organizations, including the Healthcare Information and Management Systems Society (HIMSS) Analytics (Texas Health Alliance, n.d.). The hospital introduced technology initiatives designed to increase clinical workflow, and also provide a voice for immediate patient feedback on their stay at the hospital via bedside tablets for patient use (Texas Health, 2014). Perhaps the most interesting of the innovations which this hospital operates is the command center through which it manages, equipment, patient and employee location.

Attention must be paid to the smart hospital model, and best practices developed in the civilian world should be scrutinized for applicability to Navy medicine. As Navy medicine continues to face fiscal uncertainty and increased demand for readiness and doing more with less, smart hospitals could become the necessary wave of the future. An increased focus on technology as a means to provide increases in efficiency and promoting patient outcomes could potentially allow for hospitals to operate with a smaller more efficient staff reliant on technology and information collection and analysis. The smart hospital also has potential to benefit forward deployed hospitals. With wide-spread adoption of IoT and RFID technology in hospitals both state-side and overseas hospitals, consumable supply, equipment and patient data could be collected and analyzed anywhere with network access.

Potential benefits of RFID introduction into the smart hospital model are documented in Figure 4. They are broken down into long-term and short-term benefits, with direct and indirect causation and efficiency vs. quality classifications (Buyurgan, Landry, & Philippe, 2014). The distinction between long term and short term benefits is important, particularly for Navy medicine, as initiatives enacted during one commanding officers tenure may not be realized for several years when leadership has already turned over. Given the cyclical nature of leadership turnover in the military, RFID technology should be viewed as an investment in the future, with benefits to be realized by future generations of leadership.

	Efficiency		Quality	
	Direct	**Indirect**	**Direct**	**Indirect**
Long term	Improved inventory visibility, tracking and management Reduced inventory shrinkage and misplacements Improved inventory distribution	Reduced capital and operations expense outlays Improved staff productivity Compliance with mandates Standardization in goods' identification	Improved patient satisfaction Improved care coordination Improved coordination of auxiliary services Improved infection control capacity	Reduced counterfeiting Improved price management for items Reduced care-provider turnover rate Improved patient throughput Reduced patient waiting times
Short term	Improved in-transit and total asset visibility Improved equipment tracking and tracing Reduced costs Reduced asset shrinkage and misplacements	Reduced asset surplus Ensured asset maintenance Improved patient flow Labor savings from automatic data capture and improved processes	Improved time management for caregivers Improved patient care Improved locating, tracking, and identifying specimens Improved patient tracking	Improved safety from baby/parent tracking Improved safety from patient tracking Improved safety from caregiver tracking Reduced preventable errors Improved hygiene Improved safety from expiry date and serial number tracking

Figure 4. Benefits of RFID Deployment in Healthcare. Source: Buyurgan, Landry, and Philippe (2014).

C. PATIENT SAFETY

Patient safety, one of the priorities of health care, can be positively impacted through the use of the IoT and RFID technology. RFID tag utilization for the sterilization (steam sterilizer autoclaves) process for medical and surgical equipment has seen recent innovation, and is one area where patient safety could be improved (Bendavid & Boeck, 2016; Hanada, Ohira, Hayashi, & Sawa, 2015; Cabrero-Canosa et al., 2012; Xerafy, 2015). The practice of autoclaving sterile medical equipment is an industry standard (Centers for Disease Control, 2016). Even within the standardized processes of autoclave sterilization, the risk of human error in the cleaning process still exists. The sterilization process involves hospital employees transporting contaminated equipment to the autoclave, and post-cleaning separating the equipment into sterile storage for future usage. During surgery, from time to time surgeons still accidently leave surgical utensils within patients post-surgery, numbering near 800 items since 2005 (Jaslow, 2013). The technical term for such an event is retained surgical bodies (RSBs), and they have potentially life threatening consequences resulting in further surgery for removal and correction. Although there are numerous safety checks in place to make sure all items are accounted for post-surgery, almost 80% of RSB situations happen when it is believed all items have been found and removed, only to have an item mistakenly left within the patient (Bicaj, Hamza, Zejnullahu, & Zenjullahu, 2017). Inserting RFID technology into the process of sterilization and surgical equipment tracking has the potential to positively impact patient outcomes and reduce the risk of infection from improperly sterilized equipment.

The development of these small yet durable RFID tags has taken time, and is not yet widely accepted as medical standard procedure. Navy medicine would be wise to continue to monitor developments such as the study done at New Rigshopitalet hospital in Copenhagen, where an estimated 31,000 hours were saved by introducing autoclave safe RFID tags for surgical instruments (Bendavid & Boeck, 2016; Xeraphy, 2015). Surgical trays were scanned by an RFID reader before and after leaving the operating room, ensuring nothing was missing, as well as documenting all of the steps during the sterilization process via scanning (Xerafy, 2015). The RFID tags were found to have no effect on the balance of the instruments or impede ease of use, and use cycle of the tags exceeded 1,000 autoclave cycles (Xerafy, 2015). The Shimane University Hospital in Japan also implemented RFID technology into its surgical equipment and tool tracking and tractability processes. They found improvements in patient safety as well as reduced costs and labor (Bendavid & Boeck, 2016; Hanada et al., 2015). The time it took to manage surgical instruments per surgery dropped from 150 minutes to 50 minutes (Bendavid & Boeck, 2016). The tags used are shown in Figure 5 (Hanada et al., 2015).

Top: Various kinds of housed RFID tags that are welded to the instruments. Bottom: RFID tags that are attached to the containers, baskets, and small instruments.

Figure 5. RFID Tags Used in SIMSAFE. Source: Hanada, Hayashi, Ohira, and Sawa (2015).

Patient location and tracking through the use of RFID and an IoT network also has the potential to increase patient safety and facilitate the building of a smart hospital. The Ospedale Treviglio-Caravaggio in Italy successfully implemented RFID technology to track patients within emergency department areas (Buyurgan, Landry, & Philippe, 2014). The facility seeks to improve the tracking processes as patients move from one are of care to another. Within the emergency department, 100 RFID tags are reused every time a patient checks in and out, the tags allowed staff to monitor patient location and what procedures they may have had done. If the line for an x-ray is too long and a patient instead skips a step and goes for a blood draw, with the RFID tags staff now know that the patient has skipped the step (Buyurgan et al., 2014). Benefits over the long term include increased visibility of patients and increased productivity for nursing staff, resulting in savings of €37,000 over 5 years (Buyurgan et al., 2014). RFID technology can also link specific care rooms to pharmaceutical dosage to be provided by patient (Cabrero-Canosa et al., 2012). Figure 6 provides an example of RFID tagged pharmaceauticals.

Figure 6. RFID Technology Revolutionizing Pharmaceutical Industry.
Source: Bhisey (2017).

An industry which does well with persons monitoring via RFID is the prison industry (Curtin, Kauffman, & Riggins, 2007). Although serving different core functions, the way in which the prison industry uses RFID technology could be applied to the healthcare industry in the capacity of monitoring patient location. When paired with RFID technology tracking employee locations via tags on employee badges, the potential for decreasing the time it takes to sync patient and provider location for process improvement and medical emergency management is present (Fry & Lenert, 2005).

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IV. PREPARING FOR THE FUTURE

A. OVERVIEW

Understanding the historical, current and future capabilities of the IoT, big data and RFID technology provides a big picture for the integration of technology informatics and analytics into the healthcare industry, but research into the actual implementation is necessary as well. To develop a firm understanding of the requirements for full RFID and IoT implementation, studies on organizational resistance to change, accurate scenario analysis, security challenges and the evolution of cyberwarfare should be conducted. Understanding such challenges and developing strategies to confront them in advance continues to be imperative for Navy medicine as it seeks to embrace technologies of the future.

B. RESISTANCE TO CHANGE

The healthcare industry is an extremely personal and potentially emotionally charged industry, giving due consideration to end user reactions to technological change is important to preemptively averting potential crisis and conflicts. With regards to change within the informatics field, resistance can produce positive and negative net effects (Lapointe & Rivard, 2012). Resistance that results in net positives could come in the form of a concerned employee and end user acting as a source of information, shedding light on problems within an organizations IT systems. Perhaps leadership has no idea about this problem, and without some form of resistance the problems end users face could result in inefficiencies stemming from a weakness in IT, perhaps solved with a simple fix. Unfortunately, resistance can also result in dysfunction when it causes organizational disruptions, conflict or destruction (Lapointe & Rivard, 2012). Lapointe & Rivard (2012) describe resistance to technology with five elements of resistance crucial to understanding organizational transformation regarding technology;

- “Manifestations of Resistance” (p. 889)
- “Subjects of Resistance” (p. 889)

- “Objects of Resistance” (p. 889)
- “Perceived Threats” (p. 889)
- “Initial conditions” (p. 899)

Analyzing these five subject areas and comparing them to Navy medicine as an organization provides a framework for identifying potential hurdles to implementation of an IoT, big data collection and further RFID technology (Lapointe & Rivard, 2012). Manifestations of resistance are the behaviors of discontent generated by a new IT implementation. Lapointe and Rivards’ (2012) theory building identified apathy, sabotage, denial, persistence of former behavior and the formation of coalitions as forms of resistance, ranging from weak and mild to strong but lacking destructive nature to outright destruction and disruption (p. 899). Subjects of resistance are the individuals, groups or organizations with which resistance is concerning (Lapointe & Rivard, 2012). Objects of resistance are the actual things being resisted, the targets. Perceived threats are the negative assessments made of IT systems and implementation. This can be in terms of equity or the lack of, views of fairness in terms of inputs and outputs of IT interaction. Characteristics of the environment and how it interacts with both objects of resistance and how it influences the end assessment of users are defined as the initial conditions. Pre-existing environmental conditions and previous user experiences using IT can impact the expectations of the IT implementation, impacting the perceived results and result in causal expectation (Lapointe and Rivard, 2012).

Along with potential risks and threats to IT innovation Lapointe and Rivard (2012) also discuss response categories such as “inaction, acknowledgement, rectification and dissuasion” (p. 901). In the Lapointe and Rivard (2006) study on computer information system (CIS) implementation and physician acceptance it was found that initially staff were neutral or enthusiastic about the CIS implementation (p. 1573). La Pointe and Rivard (2006) found that, “level of resistance varied and in 2 instances became great enough to lead to major disruptions and system withdrawal.” (p. 1573), and “In the other 2 cases, the implementers’ responses reinforced the resistance behaviors. Three types of responses had such an effect in these cases: implementers’ lack of response to resistance behaviors, antagonistic responses, and supportive responses aimed at the wrong object of resistance." (p. 1573). Also, "In one case, the responses were supportive and addressed the issues related to the real object of resistance; the severity of resistance decreased, and the CIS implementation was ultimately successful" (Lapointe & Rivard, 2006, p. 1573). Lapointe and Rivard (2006) found that "The 3 cases we analyzed showed the importance of the roles played by implementers and users in determining the outcomes of a CIS implementation." (p. 1573)

With regards to further developing the IoT through a big data collection initiative using RFID, resistance behaviors are an area which Navy medicine must continue to research if it wants to implement the smart hospital model. During an initial analysis of the Navy medicine's susceptibility to discontent with IT, one might think that they would be much less prone to resistance behaviors given the militaries strict structure, chain of command and federal regulation and guidelines. Navy medicine is a very diverse organization, with a workforce of active duty, civilian and contractor employees in administrative positions to surgeons operating on our nation's warfighters. One can expect that in any given command there will be a diverse mix of backgrounds, experience and technical expertise, leading to the potential for many different opinions on technological innovation within the healthcare field, and its implementation into Navy medicine. The strong organizational structure and chain of command mentality within the hospital would certainly limit strong negative reactions to IT, but there could be instances of weak and mild resistance to such change. Given the level of training and expertise developed by practitioners, any level of disruptive and intrusive technology could potentially result in negative reactions and resistance. Going into the future, Navy medicine should continue to keep practitioners involved at every stage of acquiring and implementing new RFID technologies. This will help to facilitate a smooth transition and hopefully inspire end users to become proficient quickly. It should also make sure that end users understand that although there will be some growing pains in the adoption of a smart hospital model, and the new technology that comes with it, the gains made in patient safety, efficiency and potential cost reductions should be emphasized to demonstrate the importance of these changes.

C. FUTURE SCENARIOS

When innovators and leaders begin to think about the future, identifying possible future trends and their respective probabilities is quite important. In the Botterman et al., (2012) RAND Health Quarterly 2012 Winter Issue, future RFID technology healthcare scenarios are discussed, highlighting the potential intersections of technology and medicine, with three scenarios demonstrating varying levels of acceptance towards technology and RFID and how this impacts the general population (p.xi-xiii).

Scenario 1, labeled the private care society, finds RFID highly integrated into healthcare. Patient data and healthcare is very closely held, and confidence in RFID and new technologies is high. And although the ability to bring in historically marginalized groups exist, they are still not served effectively and few incentives to get them access to the new technology and information exist. A small minority is vocal and hostile to high technology solutions (Botterman et al., 2012).

Scenario 2 is the central care society, where healthcare studies the larger population. Cost saving potentials of RFID has led to its widespread implementation, but the coercive aspect of the technology leads to resistance and refusal in the RFID enabled healthcare environment, resulting in more people being excluded from high technology based care and provided only basic services. Focus on preventative care and life style support solutions is widespread in this scenario, and medical teams are alerted of non-compliance via RFID sensors (Botterman et al., 2012).

In Scenario 3, the incident care society, only basic care is provided, with little preventative care. A medical chip store can store information such as allergies and medicine and to support delivery of care during accidents and emergencies. Chronic conditions are underfunded with a focus on more short term medical condition treatment. There is large division between occasionally unwell and long term sick older poor non-employed in this category (Botterman et al., 2012).

Of the scenarios proposed in the Botterman et al. (2012) report, a combination of Scenarios 1 and 2 seem most likely for Navy medicine in the future, given the charted goals and structure of the organization. As previously discussed, Navy medicine has a history of large population health studies in both CHAMPS and its history of EHR innovation, as well as a focus on primary and preventative care in the effort to have a readily deployable force at any time. This closely aligns with Scenario 2, and as resources potentially become more limited and efficiency becomes a greater priority, preventative medicine should continue to be increasingly important for ensuring the military is always healthy and deployable. Navy medicine's future also has the potential to align with parts of Scenario 1, as efficient technological advancements in healthcare such as RFID become more pervasive in order to provide high quality, cost efficient and productive care (Botterman et al., 2012).

D. SECURITY AND CYBER-THREATS

In an age where hacking and cyberwarfare are the next generation of threats, the security of our hospital is imperative. The network centric nature of a smart hospital creates potential for wide-spread benefits as discussed in previous sections, but the possibility that enemies and wrongdoers will seek vulnerabilities anywhere within the IoT, RFID and big data communication and collection process can almost be assured (Fu, Gunter, Kot, & Rubin, 2015). The threat of a hack to steal patient data, and the threat of identity theft and exploitation of personal information is something Navy medicine leadership must take into consideration if and when more IT solutions are pursued. Not only is patient information a target for individuals with bad intent, the dependency of technology on electrical power poses a threat to hospitals as well. In the event a power failure either from natural or nefarious purposes, the ability to continue medical procedures would be imperative (Beatty, Phelps, Rohner, & Weisfuse, 2006). If a hospital implements RFID technology to track surgical tools through the sterilization process, in the event of a power failure it is imperative to ensure backups are available to keep operating rooms open and surgical tools available for use. Scenarios such as this should be planned out by hospital leadership, particularly when contemplating implementing a new technology.

These are worst-case scenarios surely, but necessary to be taken into consideration as Navy medicine supports the warfighter directly, and is thereby a potential target of the enemy at home and abroad. Any point which captures or communicates data to the IoT is a point potentially providing access to the hospitals network in the event it is hacked. Although this requires proximity and access to the RFID scanner and receiving device, this possibility should be considered. Information warfare and cybersecurity threats continue to rise, and as Navy medicine considers IT solutions to problems, it would be wise to give due consideration to safeguarding and ensuring network vulnerabilities are not exploited.

Malware is a threat for devices and networks as well. On high-risk pregnancy monitors, malware can cause devices to malfunction, and one such example is the Haley Veterans' Hospital where an X-ray machine, mammography and nuclear medicine cameras became infected with the malware Conflicker (Blum & Flu, 2013). A strategy to mitigate malware is anti-virus software, but it still is not a foolproof strategy. In 2010, one-third of the hospitals in Rhode Island shutdown elective surgeries and only saw trauma related patients due to an anti-virus misidentifying a software component, thereby rendering it useless and disrupting workflow throughout the hospitals (Blum & Flu, 2013).

V. CONCLUSION

A. FINDINGS

Research in this project intersects the past, current and future capabilities of the IoT, RFID technology and big data, specifically within Navy medicine. Through looking into literature and studies regarding these capabilities, possible requirements for implementation and potential challenges for civilian become clearer. Given the gap in literature for Navy medicine and the IoT, RFID technology and big data, relevant findings in the civilian healthcare industry are available for application to Navy medicine to identify potential trends and larger ideas surrounding potential innovations.

Navy medicine continues to demonstrate its ability to successfully implement big data collections initiatives on an enterprise level. Therefore, it is reasonable to believe that Navy medicine has the organizational capability to successfully pursue new IoT, big data and RFID technology to further manage its population health, increase efficiencies and develop an even stronger climate of patient safety within its hospitals. Navy medicine demonstrates proficiency in implementing telemedicine technology, and should continue to pursue initiatives that limit the necessity of patient and provider face to face interaction. This also supports the facilitation of patient education.

Research supports the idea that IoT and RFID technology usage to collect and analyze big data continues to rise, along with the variety of ways it is applied. Drivers for this include pursuing cost reductions to remain profitable, generating efficiencies and providing excellent patient care to a population seeking greater access to care. An increased presence of IoT and RFID connected medical devices and instrument could become the norm in the civilian sector, further pushing Navy medicine to adopt such technologies.

The drivers of cost reduction, increasing efficiency, patient safety and patient satisfaction support continued growth of support for the smart hospital model. Although the smart hospital model brings great benefits to providers and patients, threats to this model might continue to grow as medical and administrative devices increasingly rely on technology. This technology dependence opens up these devices to threats from malware, hackers and software failure. To counter such threats, healthcare organizations should invest into IT security and assurance as necessary. The dependence of these technologies on a reliable power source necessitates staff proficiency in backup methods of supporting processes dependent on RFID and IoT connected technology.

B. LIMITATIONS

The rapid review of literature resulted in research restricted to the study of the intersection of IoT, big data and RFID technology within the healthcare industry. Research of other technologies which could leverage the IoT and big data is not a part of this study, although they likely exist. Although RFID technology has matured in many industries, it has yet to reach full maturation within the healthcare field. There are now large scale efforts to demonstrate the smart hospital model, although it remains unproven for the long-term. Autoclave compliant RFID technology for surgical sterilization is still in trial phases, limiting the research and resources available for study. The past and current IoT and big data utilization in this study are limited to research conducted via previous NPS thesis and professional reports as well as basic Internet and google scholar research. Other examples beyond this study may exist through other research and study platforms. The challenges to RFID implementation from a technical standpoint are only discussed briefly given the limited scope of the topic, but literature exists which should be further studied to understand how those unique challenges could impact Navy medicine. Differentiating between military and civilian medicine is also a limiting factor of this study. Very limited research into the IoT, big data and RFID technology as tied to Navy medicine exists. Hence, research in this study is limited largely to civilian institution and industry. Observations and recommendations are analyzed with the understanding that Navy medicine, unlike civilian medicine, requires its personnel and systems to be forward deployable and ensure warfighters are at peak medical readiness for combat. This unique difference necessitates an understanding that technologies demonstrating success in civilian medical industry may not translate to Navy medicine.

C. RECOMMENDATIONS

It is recommended that Navy medicine continue studying successful implementation of the IoT and RFID technology within the civilian healthcare sector, particularly as it pertains to big data collection and leverage. As such technologies and their usage become the norm, Navy medicine could face increasing pressures to rapidly adopt such technology, therefore identifying and adopting best practices in the civilian sector will be important. Navy medicine is encouraged to plan long term for the potential further implementation into smart hospital models, as well as pursue further telemedicine technology which it demonstrates it can successfully implement.

Monitoring the impact of cyber-security threats to the IoT and RFID technology is recommended as a priority for Navy medicine, which may require further investment into protecting its network and connected devices. Navy medicine must continue to demonstrate its ability to meet readiness standards and assure its ability to support the deployability of warfighters. Providing solutions that work with legacy technologies, while still maintaining excellent standards of care and cyber-security are difficult, but necessary for Navy medicine.

It is recommended that Navy medicine conduct A Delphi Method study into the development of a smart hospital, which could provide a variety of information for Navy medicine with regards to how members of the Navy medicine community such as providers, administrators and information technology specialists view technology implementation and its intersection with medicine as a whole. Research such as this is recommended for understanding the applicability of civilian research with regards to innovation within Navy medicine.

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