THE EFFECTS OF COMMUNICATION & TEAMWORK ON THE ACCEPTANCE OF AND PERCEIVED USE OF eICU TECHNOLOGY

A Major Paper Presented

by

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Abstract

An eICU is an electronic intensive care unit (ICU). An eICU team consists of an intensive care attending physician in collaboration with advanced practice providers and ICU nurses using remotely based telemedicine to support the healthcare team at the bedside. The eICU team functions as a sophisticated patient monitoring system and uses computerized data analysis to assist in the early identification of patient complications and to communicate these issues to the bedside healthcare team, where early interventions can be employed. The purpose of this project was to conduct a systematic review to examine whether communication and teamwork have any effect on the acceptance and perceived use of eICU technology. The articles reviewed for this study demonstrate the importance of teamwork and communication in successful implementation of an eICU. eICUs are a considerable financial investment. These papers also demonstrated that equally important to investment in technology is investment in the development of staff in the areas of teamwork and communication necessary to foster successful uptake of eICU technology.

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THE EFFECTS OF COMMUNICATION & TEAMWORK ON THE ACCEPTANCE AND PERCEIVED USE OF eICU TECHNOLOGY

Background/Statement of the Problem

An eICU is an electronic intensive care unit (ICU). According to a survey from the Leapfrog institute in 2015 survey, only 47% of all intensive care units meets the institutes ICU physician staffing standard (The Leapfrog Group, 2019). The specialized training of an ICU intensivist plays a critical role in the delivery of care in the ICU. The eICU model of care was built to bridge this gap of the critical staffing shortage of ICU intensivists in the country's intensive care units. The need for an eICU model of care was identified as far back as 1977 when a feasibility study was conducted to assess the need and ability for telemedicine consultation and routine ICU rounding between an academic medical center and a smaller hospital (Udeh et al., 2018) (Grundy et al., 1977). An eICU team consists of an intensive care attending physician assisted by advanced practice providers and ICU nurses using remotely based telemedicine to support the healthcare team at the bedside. The eICU team is a second set of eyes and functions as a sophisticated patient monitoring system and uses data analysis to assist in the early identification of patient complications and to communicate these issues to the bedside healthcare team. eICU technology has begun to take a more visible role in US ICUs and in many studies have been shown to decrease cost of care, length of stay and hospital mortality, albeit the upfront costs for establishing this model and be significant. Many health care systems have begun to weigh the significant cost of implementing eICUs in their hospitals against the positive outcomes and cost savings demonstrated with the use of this technology. More hospitals are using eICU technology and at present approximately 15 percent of US hospitals have employed eICU technology (Goran, 2010). Increased use of eICU technology has not resulted in universal ICU staff. Many studies have looked at cost and outcomes of eICU monitoring, fewer have studied the attitude of staff related to eICU technology and the impact these attitudes may have on accepting and utilizing this technology to its fullest extent. The purpose of this project was to conduct a systematic review to examine whether communication and teamwork have any effect on the acceptance and perceived use of eICU technology.

Literature Review

A comprehensive literature review was completed using PubMed, Ovid, Medline and CINAHL. The following keywords were used in the search: critical care, Telemedicine, eICU, nurses' attitudes and acceptance. The key words were searched both combined as well as separately over a ten-year period from 2008-2018.

Background

The definition of telemedicine is based on the concept of telecommunication. Telos which is the Greek prefix defines distance (Zundel, 1996). According to International Telecommunication Union's telecommunication is the use of signs, imagines, sounds and words communicated over a medium such as a wire, radio, or other electromagnetic systems (International Telecommunication Union [ITU], 1992). Telemedicine can be defined as the use of telecommunication to provide medical information (Zundel, 1996). This technology is used to not only connect medical professionals to geographically distant patients but also allows for collaboration of medical specialists who may be limited in number but can consult over long distances (Zundel, 1996). Telemedicine can range from a telephone network to real time video conferencing systems in which patients can be assessed, diagnostic imaging can be reviewed, and nurses can receive orders and provide care under the guidance of medical providers not at the bedside. (Zundel, 1996). The American Telemedicine Association views telemedicine and telehealth as interchangeable terms. TeleICU and eICU are also viewed as interchangeable terms. eICU is a collaborative interprofessional care model which connects critical care nurses and support staff at the bedside who are physically caring for critically ill patients to offsite eICU nurses, intensivists and other medical specialists through audio, video and data. The eICU nurse supports the bedside critical care nurse through additional monitoring of the patient which allows for proactive interventions and support that the bedside critical care nurse would otherwise not have ("AACN TeleICU Nursing Practice," 2018). In 2010 The American Association of Critical Care Nurses (AACN) brought together a panel of experts from nursing and the medical field to develop guidelines and recommendations for eICU nursing practice. The AACN reconvened in 2017 to update these practices and guidelines as eICU systems and usage continued to grow. The panel of experts posed questions at both conferences for example, "What is the unique contribution of the eICU nurse without which patient outcomes suffer?" AACN admits there is not enough research or evidence for strong recommendations in clinical practice, however, foresees telehealth services to continue to grow and advance. Along with this growth the eICU nurses' role has expanded to include additional interventions, risk assessments and safety measures related to physiologic instability of the critical care patient. In 2009 CCRN certification was extended to the practice of eICU nurses and designated as CCRN-E. AACN continues to push for additional research to evaluate and recommend emerging practices for the eICU nurses.

eICU History

A precise date when telecommunication was first used to assist medical providers is not known (Zundel, 1996). Although Lilly et al. cites that telemedicine first began with Willem Einthoven, the father of electrocardiography (ECG) when he transmitted EG over telephone lines in 1906 (Lilly et al., 2014). It may have gotten its first use as early as the Middle Ages in the form of bonfires or heliographs usage to warn neighboring villages about information regarding the spread of the bubonic plague (Zundel, 1996). The telegraph was used during the American Civil War to forward casualty numbers and to requisition medical supplies (Zundel, 1996). Around the 1900's the telephone was being used (Zundel, 1996). Physicians were among the first to implement its use to further their practice (Zundel, 1996). The telephone persisted as a major medium of telemedicine communication and still does today. By the start of World War I, radio communication was being used (Zundel, 1996). During the 1930's radio was being used to transmit medical information to remote areas (Zundel, 1996). During the Vietnam and Korean Conflicts, the use of radio communication was well established, being used routinely to communicate medical needs in the form of personnel and supplies via the use of helicopters (Zundel, 1996).

Telemedicine systems were established out of the development of advances made for the manned space-flight program by the National Aeronautics and Space Administration (NASA) (Zundel, 1996). To conquer time and distance in physiological function monitoring, scientists and engineers at NASA developed biomedical telemetry and other telecommunication systems specifically for the use of biomedical applications (Zundel, 1996). NASA showed that astronauts in space could be successfully monitored remotely by medical personnel on earth while during space flight. Physiological function monitoring included: heart rate, blood pressure, respiration rate and temperature (Zundel, 1996). This monitoring was important to NASA because of the concern to monitor, diagnose, and manage inflight emergencies resulting from extended length of space flights (Zundel, 1996). NASA brought to the forefront a corresponding link between the needs of physicians on the ground, trying to monitor the health of astronauts in space and the physicians trying to do the same with patient in remote areas of the country (Zundel, 1996).

Another significant influence in the establishment of telemedicine was introduction television (TV) (Zundel, 1996). In the 1950's closed circuit TV and video communications began to be used in the healthcare setting (Zundel, 1996). The first interactive video link was established between the Norfolk State Hospital and the Nebraska Psychiatric Institute in 1964 (Zundel, 1996). The first complete telemedicine system connecting healthcare personnel to physician-patient encounter setting started in 1967 connecting a medical clinic at Boston's Logan Airport to Massachusetts General Hospital. In the initial phases of the project, medical researchers proved that remote diagnosis was possible through interactive TV and the ability to effectively transmit laboratory data and X-rays, (Zundel, 1996).

In the 1960's and 1970's federal funding was provided to implement seven pilot telemedicine projects (Zundel, 1996). The aim of these projects was to help establish the capabilities of equipment needed as well as the clinical practicability of the concept of telemedicine for solving specific problems in medical care including access to care (Zundel, 1996). These pilot studies took place in several different settings. Each test site provided different possibilities in which to test the potential of telemedicine to address specific sets of medical care problems, along with other areas of further investigation (Zundel, 1996).

Most of these pilot programs were developed in rural areas where staffing was the most critical issue. But despite the numerous projects, a decisive conclusion regarding the best use of eICU was not obtained (Zundel, 1996). Answers were found to some of the questions, but results recommended more research for others. The feasibility of establishing the technological base for telemedicine was verified (Zundel, 1996). These pilot studies definitively confirmed that telecommunications could be used to increase coordination and extend medical care in large healthcare institutions such as hospitals systems (Zundel, 1996). Telecommunication in healthcare could be used as an alternative for travel to obtain medical care and more importantly it can be used to establish a crucial link between physician and patient in critical and emergent situation (Zundel, 1996).

The initial objective of telemedicine was to assist in the delivery of healthcare specifically, consultation and diagnosis, to individuals that are geographically separated from physicians or pertinent medical care. In 1950, Gershon-Cohen wrote an article entitled, “Telognosis”, which was a compression of three terms: *teleo* meaning distance, *roentgen* meaning X-ray, and *diagnosis* meaning diagnosis. Telognosis meaning was the X-Ray diagnosis gained from facsimiles transmitted via radio or telephone wires over short and long distances (Zundel, 1996). He reported that the system had been used regularly for the past two years successfully in Pennsylvania and that his facsimile procedure of diagnosis could provide expert X-ray service to staff in remote rural facilities (Zundel, 1996). In an issue of the USA Today newspaper from July 1994 an article was written about a 6 million-dollar remote teleradiology center. The facility was able to transfer computerized tomography (CT) scans, magnetic resonance imaging (MRI) scans, mammograms, ultrasounds, over fiber-optic wires to the University of California Medical Center. There all the results of these diagnostic tests were able to be read by thirteen radiology subspecialists that worked in the facility which ensured quick and accurate interpretation of the results (Zundel, 1996).

The Maritime Health Service (MHS) in 1990 initiated an occupational health service which allowed the medical officer on board a fishing trawler to have direct communication access with a physician whenever needed at any time (Zundel, 1996). This telemedicine system became known as the Medical Consultation Network (MedNet) (Zundel, 1996). It is a video communications application based on a video-conferencing platform. Ocean vessels can establish real-time link to an emergency physician at the MHS (Zundel, 1996). MHS has expanded the MedNet application to comparable situations such as cruise lines, private yachts including some land-based situations such as logging camps, mining sites, and expeditions (Zundel, 1996). The MedNet allows for visual information from remote patients and extends the accessibility of appropriate, professional emergency medical care, thus saving lives and money (Zundel, 1996).

During the 1970's telecommunications approaches were developed to expand specialty services to an increasing number of patients (Zundel, 1996). The basic premise in many of these telecommunication pursuits was that having the specialists physically present was unnecessary. It would be enough to transmit relevant data to the geographically separated specialist for them to make diagnosis and recommend a treatment plan (Zundel, 1996). Since the 1970's subspecialties have been increasing the use of telemedicine as part of their practice.

In the 1990's, the Oregon teledermatology project was started. It was part of the National Library of Medicine's (NLM) portion of the High-Performance Computing and Communications (HPCC) initiative (Perednia & Brown, 1995). The Oregon HPCC teledermatology project was designed to bridge the dermatologic care gap and improve the delivery of care using innovative high-speed computers, computer networks, and full-color digital image storage (Perednia & Brown, 1995). Dermatology as a specialty is lacking expertise in remote areas making patients in those areas more them susceptible to skin-related deaths (Perednia & Brown, 1995).

In the 1989 a study was published in The American Journal of Cardiology in which a 24-hour telephone service was established for pediatric echocardiography communication between a large hospital and a children's hospital that was 500 km away. Studies were sent in over telephone lines for interpretation and diagnosis by a pediatric cardiologist immediately (Zundel, 1996). This was the first report of echocardiographic transmission by telephone. The study showed that telemedicine in the area of pediatric cardiology was achievable, and cost-effective. It allowed for emergency access to specialist expertise and could prevent possible expensive transport of ill children (Zundel, 1996).

A project was conducted in the 1970's to assess whether the use of closed-circuit TVs was an appropriate medium for psychiatric examination and discussion. This was a successful means of keeping clients in the community while being able to assist non-psychiatric physicians with recommendations and education (Zundel, 1996).

Telemedicine has been used in critical care as far back as 1977. An article published then which described how the use of the use of telemedicine was used to help solve the problem of limited number of critical care intensivists as well as the poor distribution throughout the country. The author highlighted how regular consultation via a two-way audiovisual telemedicine link was able to positively impact patient care by improving patient outcomes (Zundel, 1996). It described how this telemedicine connection linked a small private community hospital to a large tertiary university medical center and the resources that are available, including specialists. The study also noted that the audiovisual connection was significantly better than telephone consultation and improved consultation as an educational resource (Zundel, 1996).

Telemedicine was used in 1995 in the oncology setting for the purpose of consultation of pediatric oncologists in south Texas. A smaller community hospital did not have that type of specialist on staff. A telemedicine system was used to link with The University of Texas Health Sciences Center in San Antonio to decrease travel costs and increase availability to outlying rural community hospitals in Texas (Zundel, 1996).

There have been other uses of telemedicine beyond consultation. In 1990's the Alzheimer's Disease Support Center (ADSC) in Ohio started a project where telemedicine was used for patient and family teaching and support (Zundel, 1996). Often dementia related support groups are hindered by the ability of family members to get to them due to geographic location, physical setting, and/or scheduling (Zundel, 1996). The ADSC created five modules to help educate family members and caregivers about the disease. They could access these modules via a telecomputing system linking computers via telephone lines and modems (Zundel, 1996). In Massachusetts, Harvard Community Health Plan started a pilot study where 150 household participants used a computer program to obtain medical guidance and general health & wellness information on various topics. There were three main goals of the study: lower costs by reducing unnecessary medical visits, enhance patient knowledge and increase the quality of care.

At the end of the study, 90% of the participants gave the system high ratings for ease of use, usefulness, and accuracy (Zundel, 1996).

Remote home monitoring of patients has been noted in the literature as far back 1987. The monitoring of patients via telephone and TV allows providers to observe vital signs. They are even able to monitor blood chemistry via transdermal patches (Zundel, 1996). Communities even started to use panic button devices for the disabled and the elderly where they could send for emergency medical services (EMS). Remote monitoring of cardiac devices and pacemakers were being linked to telecommunication systems to examine crucial information (Zundel, 1996).

Telemedicine has even been used in the advancement of continuing medical education as of 1993. Since then, audiences can be present and observe groundbreaking medical procedures and pioneering surgeries via live satellite feeds, linking these remote audiences over thousands of miles (Zundel, 1996).

The definition of telemedicine has changed over time as technology has improved. The current definition of telemedicine according to the Merriam-Webster Dictionary is “the practice of medicine when the doctor and patient are widely separated using two-way voice and visual communication (as by satellite or computer)” ("Telemedicine," 2019).

It was not until the turn of the millennium that the first eICU, led by intensivists started to be researched (Lilly et al., 2014), in a sixteen-week study of a 24-hours off-site ICU at the Johns Hopkins University School of Medicine. Researchers used controls from the prior year to compare outcomes with remote eICU. The study demonstrated a significant reduction in severity adjusted ICU rate of 60% and mortality rate by 30%.

This validated that remote ICU care could be achieved successfully and contribute to significant beneficial outcomes when assessed against historical parameters (Lilly et al., 2014).

As technological advances have been made, data collection and analyses have developed to include many other information systems such as: clinical decision support systems, pathology laboratory systems, all-inclusive monitoring systems, communication systems, the ability to archive past radiological scans (Lilly et al., 2014). These advancements in telemedicine in the ICU have helped transform it into a technology system all its own called teleICU technology or eICU technology.

It has been understood for some time that the Intensivist model is the gold standard when it comes to ICU care. In 2000 the Leapfrog Group proposed that patient outcomes are better in an "intensivist-model" (ICUs) than in ICUs without that model (Young, 2000). The Leapfrog Group is an advisory board of multiple fortune 500 companies which help regulate purchasing standards based on identified evidence-based recommendations for enhancing quality care while decreasing costs (Manthous, 2004). The data was sourced from an extensive literature review of the MEDLINE database from 1986 to 2000 that revealed all studies of the reduction in mortality rate were associated with intensivist-model ICUs. In the nine studies that met the selection criteria, reductions of mortality rates ranged from 15% to 60%. Using the conservative percentage of 15%, full implementation across the country would ultimately save approximately 53,850 lives each year (Young & Birkmeyer, 2000). While the intensivist model was validated by Young in 2000, confirming the Leapfrog Group findings, there has been a shortage of intensivists to staff all ICUs. According to the Leapfrog Group, an intensivist is a physician who is board certified and has an additional certification in a subspecialty of critical care of: medicine, anesthesiology, pediatrics, emergency medicine, or surgery, they must also have completed training prior to the subspecialty certification as well as completing a minimum of six weeks of full-time ICU care each year (The Leapfrog Group, 2019). This is also called the Leapfrog IPS Standard (The Leapfrog Group, 2019). According to the latest results from a 2015 survey, only 47% of all intensive care units meet Leapfrog's ICU physician staffing standard. This standard includes that ICU physicians are certified intensivists, who are present in the ICU for eight hours per day, seven days a week and that they can respond to pages within five minutes (The Leapfrog Group, 2019).

Over the last half a century there have been a numerous hurdles standing in the way of expansive implementation of telemedicine technology. Technological and financial challenges made it more difficult to advance telemedicine implementation. Healthcare reforms are now bringing about necessary changes for this to happen. (Gruessner, 2015).

In March 2010, President Obama proposed 'Connecting America: The National Broadband Plan' to contribute to the enhancement and spread of broadband networks across the country. This strategy of improvement of medical networks that enable remote patient monitoring, electronic health records, and other technology-based health benefits such as telemedicine (LeRouge & Garfield, 2013).

The American Recovery and Reinvestment Act (ARRA) of 2009 and the Health Information Technology for Economic and Clinical Health Act (HITECH) which is a subset of the previous Act, were two pinnacle pieces of legislation that brought about a mass of reforms and medical technology advancements (LeRouge & Garfield, 2013). The Patient Protection and Affordable Care Act led to the conception of Accountable Care Organizations (ACOs). The goal of ACOs to improve care synchronization among medical facilities throughout the continuum of care and create a culture of teamwork among all providers that provide care to an individual patient. Telemedicine technology plays a critical part in care coordination, which means the Affordable Care Act (ACA) and conceptualization of the ACOs are truly intertwined and critically responsible for the advancement of these technologies (LeRouge & Garfield, 2013).

The American Telemedicine Association (ATA) implies that there can be valuable uses of telemedicine within the ACO model. Telemedicine will help coordinate specialty services, allowing access to more service sites, and reducing the cost of care. When originally constructed, the ACA had limitations on Medicare reimbursement of telemedicine. Many organizations including the ATA, have called for rescinding those restrictions (LeRouge & Garfield, 2013).

eICU Technology in Practice

The AACN defines TeleICU or eICU as, “a collaborative interprofessional care model focusing on critically ill patients that is enabled by leveraging audio, video, data, and other technologies to engage critical care experts in patient care, along with clinicians at collaborating sites” ("AACN TeleICU Nursing Practice," 2018, p. 3). The eICU is an area of nursing and medicine where informatics and telecommunications are used to provide professionally driven evidence-based ground-breaking services to monitor and provide treatment for ICU level of care patients (Williams, Hubbard, Daye, & Barden, 2016). The eICU is most often in a separate location from the ICU beds that it monitors, therefore the nurses and providers in the eICU have no “hands-on” contact (Stafford, Myers, Young, Foster, & Huber, 2008). It is often called the command center, or hub which is networked to the bedside ICU teams in which the eICU personnel and technology deliver support to the bedside care team through collaborations between the eICU staff and the bedside ICU staff. This central monitoring facility (hub and spoke) model puts an intensivist-led team where they can be responsible for 50–500 remote ICU beds. It is not a replacement for the bedside team, but rather a support system to continuously advance the established plan of care.

In addition to the assigned attending intensivist who usually provides exclusive care in the ICU during the daytime hours, the teleintensivist who monitors the ICUs remotely during the overnight hours, is responsible for the management of the patient during this time (Williams et al., 2016). This usually includes prescribing medication or diagnostic tests, managing interventions of the critically ill patient when the primary intensivists are not physically available (Williams et al., 2016). They can intercede and help assist in emergency circumstances when the patient’s situation declines. They can help educate and guide nurse practitioners (NPs) or physician assistant (PAs) conducting beside procedures, such as bronchoscopies or difficult intubations (Williams et al., 2016). They can also teach and mentor novice nurses in bedside interventions for example, cardioversion of a patient who is presenting with unstable symptoms as well as many other critical interventions (Williams et al., 2016).

This technology uses this synthesized information which is funneled through predictive algorithms to help triage and prioritize patients and identify the need for earlier interventions. The results of these algorithms are used by both providers and nurses at the eICU remote location as well as the bedside ICU nurses and providers. The eICU physicians and nurses execute preconstructed protocols to intercede in emergencies when a patient's attending intensivist is not in the ICU. This gives an additional layer of safety or a second set of eyes on the patient (Williams et al., 2016) while also offering the care team the ability to reduce the time between problem identification and intervention.

This communication between the eICU and the bedside care team can take place over real-time audio or video link. This is an on-demand technology in which either side can request immediate consultation (Williams et al., 2016). With the help of these predictive algorithms and the eICU technology, the eICU staff can oversee numerous ICU patients at the same time (Williams et al., 2016). They have access to all the information the beside care team does real-time: medical records, laboratory results, recent diagnostic testing, continuous ECG, and hemodynamic values (Williams et al., 2016).

A critical responsibility of the eICU nurse is rounding on the patients that are assigned to them. This is done by using the real time camera, which is in the room, in which the eICU nurse completes an assessment of the patient and the environment which includes: safety check, verification of intravenous fluids (IVF), pump settings, vent settings if appropriate and physical appearance of the patient (Williams et al., 2016). Most often, the frequency of the virtual rounds is determined by the patient's acuity. The acuity is categorized into a color-coded system: red, yellow, and green. This categorization is based on three criteria: physiological outlook, therapeutic measures, and safety risk (Williams et al., 2016).

Another important aspect of the eICU nurse role is as a resource for the bedside ICU nurse (Williams et al., 2016). Because the eICU has access to all the same information as the beside nurse, they can retrieve critical pieces of information saving the bedside nurse time. They can act as a stand in for "Time outs" for bedside procedures. They also can write detailed admission notes so that all providers and nurses have a complete picture about the patient (Williams et al., 2016). The eICU nurse also ensures the critical care team adheres to best practices for example, ensuring that sepsis and VAP bundles and protocols are met. They can follow-up on laboratory findings or other diagnostic testing. They can take over close monitoring while the bedsides nurse is tending to another patient or while transporting a patient.

eICU Benefits

Critical care units provide advanced medical care to the sickest of patients. As our population ages and increased availability of advanced medical and surgical technology research has shown more favorable outcomes with 24/7 intensivist coverage (Udeh et al., 2018). However, with a shortage of intensivists and the high cost of 24/7 intensivist coverage, this model is not always feasible (Udeh et al., 2018). This shortage and increased cost of providing 24/7 intensivist coverage is one of the primary influences in eICU implementation. With eICU, one intensivist may be able to manage up to 130-150 patients, compared to some 50-75 patients per intensivist without eICU (Ward et al., 2013). The main drivers for the implementation of eICU technology are to leverage sparse resources and to improve the quality and safety of patient care (Goran, 2012) while decreasing clinician and staff burnout.

The eICU program's ability to enhance quality can be based largely on three central outcomes benchmarks: 1.) clinical measures, such as severity adjusted mortality, compliance to best practice recommendations, and length of stay (LOS), 2.) customer satisfaction and, 3.) financial outcomes (Goran, 2012).

Physiological variables a can be used to quantify the severity of critically ill patients and help provide risk stratification and be able to provide outcome evaluations. Many organizations use the APACHE IV (The Acute Physiology and Chronic Health Evaluation) scores. These scores are constructed from (LOS) and severity adjusted mortality forecasts based on physiological data along with other information including chronic health items, admission diagnosis, age, and admission source (Zimmerman, Kramer, McNair, & Malila, 2006). These scores are frequently used to determine the ICU performance for benchmarks against itself, other ICUs within a hospital system or against national benchmarks (Goran, 2012).

A constant effort to comply with care bundles and protocols, providing the right care at the right time to reduce the occurrence of sepsis or ventilator-associated pneumonia (VAP) is paramount. Collaborations between the bedside ICU care team and the eICU have shown promise in increasing bundle and protocol compliance (Goran, 2012). Other areas of significant improvement highlighted in the research related to the partnerships between eICU team and the bedside team are improvement of glycemic control, reduction of cardiac arrests, improved prophylaxis of deep vein thrombosis (DVT), increased compliance with referrals to organ procurement agencies and a reduction in ventilator days (Goran, 2012).

The eICU team can review individual patient plan of care during virtual rounds without distractions the normal ICU presents. They can audit care bundle compliance and can either bring omissions to the attention of the bedside care team or providers and can enter an order to ensure achievement of compliance (Goran, 2012). The eICU can function as backup resources for less experienced staff or be used as an extension for consultation for medical residents (Udeh et al., 2018).

There are many other positive outcomes that arise from the use of eICU technology. There are multiple eICU interventions which have been shown to have positive outcomes for patients. These assessments can influence clinical assessments of physiological trend alerts, alerts for abnormal lab and diagnostic testing and eICU virtual rounding by the eICU team (Udeh et al., 2018). In 2011 Lilly et al found 80% of eICU interventions occurred when the bedside critical care team was not present. Although a small proportion of these intervention were lifesaving, 57% of the interventions changed the care plan for the patient. In 2011, Lilly et al looked at 6,290 patients in 7 ICUs and of the ICUs that utilized eICU technology there was an increase in best practice adherences of the prevention of ventilator-associated pneumonias, catheter-related infections, pressure ulcers, and deep vein thrombosis (Lilly, Cody, & Zhao, 2011).

A systematic review and meta-analysis by Chen et al., 2017 found that the use of eICU programs reduced ICU mortality significantly, looking at fifteen studies, and 166,436 patients. In the same review and meta-analysis looking at thirteen studies and 183,209 participants that hospital mortality was reduced. Length of ICU stay was also analyzed across nine studies which showed the use of eICU programs significantly contributed to decline in ICU days.

Much of the earlier benchmark data trying to identify the relationship between APACHE scores and the implementation and use of eICU programs was inconclusive. Several factors contributed to this ambiguous picture: variation of how the eICU was defined and implemented in the studies, how the eICU model used, such as did the hospitals use the eICU for covering other ICUs in their own systems staff or was the coverage outsourced to other hospitals for coverage of a small community hospitals independent of the eICU (Goran, 2012). Other researchers suggest a major contributing factor to mixed results in past research was the lack of conceptual framework when studies were conducted especially having to do with the impact on mortality and LOS. Despite earlier research showing ambiguous results, now most of the comparison information indicates that that there is a relationship between eICU programs and improved patient mortality (New England Healthcare Institute, 2010).

Impact of Cost: Fiscal Return on Investment

A major drawback to the implementation of eICU technology is the upfront cost of the program. According to a systematic review and meta-analysis by Chen et al., 2017 it costs approximately $50,000 to $100,000 dollars per ICU bed to implement eICU programs for the first year. Another finding was that eICU program savings promised to the healthcare system by the technology companies were not always realized. In one study they found that hospitals had a cost savings of $2600 per patient and others in another study hospitals increased in spending per patient by $5600 (Chen et al., 2017). In this same systematic review and meta-analysis, in eight studies, hospital length of stay had no significance difference between hospitals that use an eICU program and those that use conventional ICU care. The researchers were able to infer that eICU programs in hospitals such as tertiary care hospitals, academic medical centers, urban facilities, and hospitals with centralized structured eICU models benefit from eICU programs whereas in institutions with less intensivists staffing in community hospitals or rural hospitals eICU programs have no substantial difference on ICU mortality (Chen et al., 2017).

Implementation of eICU technology and program are extremely costly to implement. LOS is the most critical determinant of ICU cost. It makes sense that eICU technology and eICU programs that decrease the ICU LOS should be related to institutional savings. Nevertheless, this reduction in the ICU LOS does not translate into a decrease of overall costs. This is because hospital organizations have a difficult time determining where all the costs originate (Ries, 2009). Severity of illness is a significant variable and the disparities in costs structures complicates the ability to see cost savings (Goran, 2012). Hospital executives are calling data and information that can demonstrate a cost savings a return on investment (ROI). The intricacies underscored in the capability of the eICU programs to validate the financial ROI can be corroborated by the lack in number of published studies. Notwithstanding the challenges associated to with the explanation of potential ROI, the cost of quality care will only become more apparent as financial incentives become more and more tied to quality indicators (Goran, 2012). Cost savings may also be realized with a reduction of patient complications commonly associated with care in the ICU such as VAP. A reduction in central line-associated bloodstream infections (CLABSI) or catheter associated urinary tract infections (CAUTI) may provide other opportunities of cost savings linked to eICU programs (Lilly et al., 2011).

Another area of cost avoidance where saving has been significant is in the reduction in malpractice expenses. In one study, the occurrence of malpractice claims and acquired costs were considerably lower at eICU sites compared to that of ICUs without eICU coverage. This occurred in a large 450-bed eICU system covering five states (Lilly et al., 2014.)

Barriers to eICU Acceptance

The essential interdependence of the ICU and eICU can be an impediment to successful implementation or expansion of eICU programs and services. According to Wilkes and colleague's ineffective partnerships have been linked to suboptimal patient outcomes and safety, poor satisfaction scores of patients and families, poor retention of staff and higher costs (Wilkes et al., 2016). eICU technologies can worsen communication issues and impair the effective collaboration dynamic between bedside staff and that of the eICU (Wilkes et al., 2016).

Patient & families are certainly affected by the role that the eICU plays in patient care. There is minimal amount of research related to customer satisfaction with an eICU experience. According to a pilot study by Jahrsdoerfer & Goran in 2013, there were significant gaps in communication about the use of eICU between staff and a patient's significant others. According to the study, 66% of respondents had not been informed that their loved one was receiving care in an ICU with eICU collaboration. Despite this finding significant other's responses towards the use of eICU technology were positive but they wish that they had been informed about the use of eICU in the care of their loved one (Jahrsdoerfer & Goran, 2013). Nurse turnover rates related to dissatisfaction of working conditions can be frequent & costly (Goran, 2012). Working relationships can be more difficult within interdisciplinary teams that are geographically separated (Wilkes et al., 2016). Wilkes and colleagues learned that bedside staff often felt like they were being watched and belittled. Acceptance or barriers in the use of eICU technology is shaped by the individual culture of each ICU and its leadership (Goran, 2010).

Communication & Teamwork

Healthcare today is delivered by multidisciplinary teams as opposed to individuals. Changes in healthcare delivery have not been supported by modifications in the systems for communication between health professionals, especially across healthcare disciplines (Weller et al., 2014). Communication breakdown and interprofessional failures directly lead to compromised patient care. To achieve optimal functioning teams, members must respect and trust each other to give and receive feedback. They must have good communication skills to accurately share information. Effective teams must have a shared mental model. Shared mental models leads to a common understanding of the situation, the roles, and tasks of the individuals in the team, and the treatment plan. Without a shared mental model, team members cannot participate in problem solving and decision making. The sharing of information is a vital requirement for effective team performance. A meta-analysis of 72 individual studies across an array of industries revealed that information sharing positively predicted the performance of the team. Dissemination of information is required for safe & effective patient care, especially in high-acuity settings. Breakdown of information sharing is related to three factors areas: educational factors, physiological factors, and organizational factors (Weller et al., 2014).

Recently significant attention has been addressed regarding provider-patient communication, yet less is being done to train medical students how to communicate with other health professionals. Education for health professionals continues to be mainly discipline-specific, with minimum interaction between healthcare specialties. Most training occurs in professional silos and few healthcare professionals receive specific training in teamwork. This separation does little to address the understanding of the roles and responsibilities of others in the multidisciplinary team and contribute to problems when collaborative teamwork is necessary (Weller et al., 2014).

The development of a professional identity is crucial part of professional education but there is a consequence to this identity expansion. Social identity theory explains that professional grouping such as nursing, medicine, other allied health professionals and subspecialties like surgery tend to see their professional qualities in a more positive light and those of other groups in a more mediocre way. Certain personalities are attracted to certain professions and specialties which contribute to a reinforcement of this tribal phenomenon (Weller et al., 2014).

An additional psychological barrier to effective communication is the basic hierarchal structure itself. Less senior staff may not feel they are able to offer suggestions, suggest alternative diagnoses or question judgments. This type of industry structure proved to have devastating repercussions in the aviation industry where junior pilots failed to challenge misdirected judgements of senior pilots (Weller et al., 2014).

Organizational barriers like geographically distributed teams increases the potential for communication failures & breakdown (Weller et al., 2014). The layout of the hospital and the location of the patients within the hospital, effects the efficiency of patient care teams. For example, care plan meetings, and patient rounds. These factors act as barriers to the dissemination of information. Multidisciplinary team members who may have important information to foster positive patient outcomes may not be able to be attend team meetings. Those team members may have information that needs to be communicated but the environment is not advantageous to completing this.

Learning how to improve & enhance communication is a priority for healthcare teams. There are many approaches to improve information sharing in the healthcare setting. Many of these methods have been identified by other industries which healthcare can learn from. Healthcare professionals need to be taught effective communication strategies. Health professionals' verbal communication skills should match their factual knowledge and skill set to preform procedures and assessment. Teaching structured methods of communication such as 'SBAR' handovers can enhances communication. Teams that work together should train together. Training that includes all members of the team improves outcomes. Simulation training is a safe way to practice communication skills and it increases interdisciplinary understanding. Simulation learning with post scenario debriefing provides understanding about how other professional groups think and feel. This gives the team insight how to support each member and how to expand their contribution to patient care (Weller et al., 2014).

Healthcare teams need to redefine themselves. The team needs to change from a collection of professional disciplines seeing themselves as individuals, to a cohesive team defined by common goals. The team needs to be stressed over any one discipline. Teams need to be democratic, not hierarchical. The environment of the team must be such that all members need to be confident that their voice will be heard. Each member must be encouraged to share information in the decision-making process. When team members feel that they are respected, and their contributions are valuable and recognized, then trust is achieved. Improvement in teamwork can lead to significant gains: increased patient safety, better efficiency of care, reduced complication rates and reduced mortality (Weller et al., 2014). .

Creating a successful high-performing interdisciplinary team is critical to the success of an eICU program. Each healthcare organization (HCO) may have its own organizational culture, procedures, and clinical practices. Cultural norms, teamwork structure and communication standards may be different. These influences can have significant bearing on partnerships and teamwork. Wilkes et al., 2016, found that cooperatively established program standards, teamwork and communication were central factors that affected the success of the eICU program. Program sites that did not show respect and value each other's expertise had lower rates of use of eICU program. Forming mutually continuing education plan which focuses on cultural mindfulness and communication was especially important. Shared acknowledgement for team members role and responsibilities must occur for collaboration to take place (Wilkes et al., 2016). 79% of bedside ICU nurses thought that personally knowing the eICU provider was key factor. 61% of the respondents said they more app to contact the eICU if they knew the provider who was there (Wilkes et al., 2016).

Acceptance & Perceived Use

A healthcare system may invest millions of dollars into an eICU program. It would be inconceivable to think that quality outcomes and indicators would improve without the acceptance and support of the bedside ICU staff (Goran, 2012). The productive incorporation of the eICU team into the care team requires the collaboration of goals, respect, and knowledge (Canfield & Galvin, 2018). Acceptance of information technology is "the demonstrable willingness of a user group to employ information technology for the tasks it is designed to support" (Rufo, 2012). Acceptance goes beyond just the agreement to use specific technology, it requires verification of usage to perform tasks and realization of outcomes proposed by the creators of that technology. Further, acceptance can be demonstrated and forecasted (Rufo, 2012). The acceptance of eICU technology by clinical staff is essential for both financial and clinical outcomes (Udeh et al., 2018). Previous studies of acceptance of the eICU technology has yielded varying results.

Nursing leaders may benefit from conceptualization of changes theories, especially the Technology Acceptance Model, when developing interventions for acceptance and buy-in from bedside staff (Kowitlawakul, 2011). Cultivating a positive working relationship between the bedside ICU and the eICU nurses is essential in the promotion of optimal functionality between these interdisciplinary teams. This is accomplished by fostering a sense of teamwork and promoting effective communication thus ensuring optimal patient care (Canfield & Galvin, 2018).

Next, the theoretical framework will be presented.

Theoretical Framework

The theoretical framework for this systematic review is the Technology Acceptance Model (TAM), developed by F.A. Davis (1989), to determine the factors that influence an individual to accept or reject an information technology. He posits that the two most important principles that guide the individual about using an information technology are perceived usefulness and perceived ease of use.

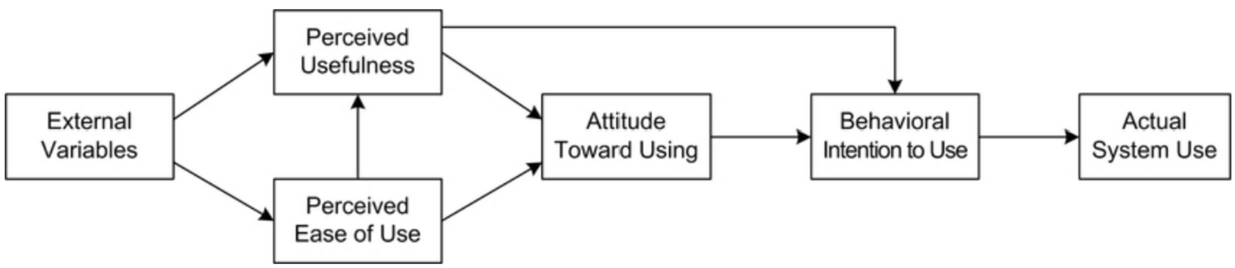

Figure 1. The Technology Acceptance Model (TAM) (Davis, 1989)

The TAM is built on the Theory of Reasoned Action (TRA) developed by Fishbein, M., & Ajzen, I. In 1986, Davis modified the TRA to create the TAM. The TRA is a theory that explores the elements of intentional behaviors (Fishbein & Ajzen, 1975). The TRA was intended to justify human behavior throughout a myriad of areas (Davis et al., 1989). Whereas the TAM is specifically meant to explain the behavior of computer usage. The goal of TAM is to explain, predict, and identify the key determinants of computer acceptance or why a system is undesirable (Davis et al., 1989). The TAM is much narrower in scope but general enough to permit use with many types of populations, industries and computer systems (Davis et al., 1989).

There are five tenets, in the original TAM: perceived usefulness, perceived ease of use, attitude toward using, behavioral intention to use, and actual system use. The key and dominant elements of computer acceptance in TAM are perceived usefulness and perceived ease of use. Davis described perceived usefulness as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320). He explains that perceived ease of use is explained as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989). These two individual tenets of perceived usefulness and perceived ease of use lead to the individual’s behavioral intention follow by their actual behavior. Davis’s work discovered that perceived usefulness is the stronger of the two predictors of an individual’s intention to use an information technology (IT).

In the information systems and technology field, The Technology Acceptance Model have been extensively used by investigators to study the potential adoption and integration of numerous technologies. The TAM has debatably become one of the most prominent theories to test research in the information systems field. Researchers have also modified and extended the TAM over the last couple of decades and have added different factors or concepts that seek to find influences of the intention of use (Wixom & Todd, 2005). Two key and dominant determinants remain from the original TAM: perceived usefulness and perceived ease of use. These have still been used as forecasters of technology acceptance in numerous studies (Venkatesh, 2000). Szajna found that the original TAM may be more suitable for forecasting the intent to use an information system than two-version revised TAM that she studied. (Szajna, 1996). The purpose of this project was to conduct a systematic review to examine whether communication and teamwork has any effect on the acceptance and perceived use of eICU technology.

Next, the methodology of the systematic review will be described.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was developed to allows the reader full transparency to assess the strengths and weaknesses of any systematic review This includes a 27-item PRISMA checklist (Appendix A) and four-phase flow diagram (Appendix B), which are used to provide consistent findings, reduce bias and to permit for precise conclusions to be drawn from the systematic assortment of studies. There are seven major sections found within the PRISMA checklist: the title, abstract, introduction, methods, results, discussion, and funding. These sections include detailed information, summarized, and reported with substantiating data as to why a study should be included. The four-phase PRISMA flow diagram displays the flow of information from the initial search where all articles are evaluated for their relevancy to the topic being examined. This provides authors with a roadmap for narrowing results in a manner that is reliable and replicable. The diagram shows number of duplicate records excluded, records that were screened, records that were included and excluded and the reasons for exclusion. Because of the high reliability and reproducibility PRISMA was used to conduct the data search for this systematic review.

Purpose

The purpose of this project was to conduct a systematic review to examine whether communication and teamwork has any effect on the acceptance and perceived use of eICU technology.

Research Question

Does communication and teamwork effect the acceptance and perceived use of eICU technology?

Inclusion and Exclusion Criteria

Inclusion criteria includes bedside ICU nurses, tele-ICU nurses, critical care intensivists, advance practice registered nurses (APRN), physician assistants, medical residents, respiratory therapists: Studies in the intensive care unit (ICU) setting, whether at the bedside unit or the tele-ICU or eICU; available in English language; all study designs.

Exclusion criteria included non-critical care, tele-icu, eICU; centered around patient/family acceptance or satisfaction, non- English.

Search Strategy

A literature search was conducted using the search engines PubMed, Ovid, Medline and CINAHL. Keywords used in the search: critical care, Telemedicine, eICU, nurses' attitudes and acceptance, communication, teamwork. These key words produced 133 articles which were then chosen based on their relevance to this topic. The PRISMA flow diagram was used to evaluate the eligibility in an impartial and methodical fashion. A complete history of search terms and results were logged throughout the process and then examined to eliminate any duplicate records.

Data Collection

The data was organized in a collection table (Table 1). The data collected included the title of study, author(s) and aim or purpose of the study. Other relevant data complied included the design or type of study, sample of participates including their number, method or how the study was conducted and the outcomes of the study.

Table 1. Data Collection Tool

Site/Sample	Method/Design	Communication Measures	Teamwork Assessment

Dissemination of Findings

Findings from this systematic review were disseminated through a major paper and poster presentation. The optimal audience reached was nursing masters' students, clinical nurse specialists and nurse practitioners. These APRNs will be able use this knowledge base to relate the important factors of communication and teamwork and their application to the ever the advancing healthcare technologies such as eICU technology.

Next, the results section will be discussed.

Results

The PRIMSA flow diagram (Appendix B), as well as the inclusion and exclusion criteria previously discussed, were utilized for the selection of articles included in this systematic review. The PRISMA flow diagram exhibited below (figure 1.) displays the breakdown of the search strategy.

PRISMA 2009 Flow Diagram

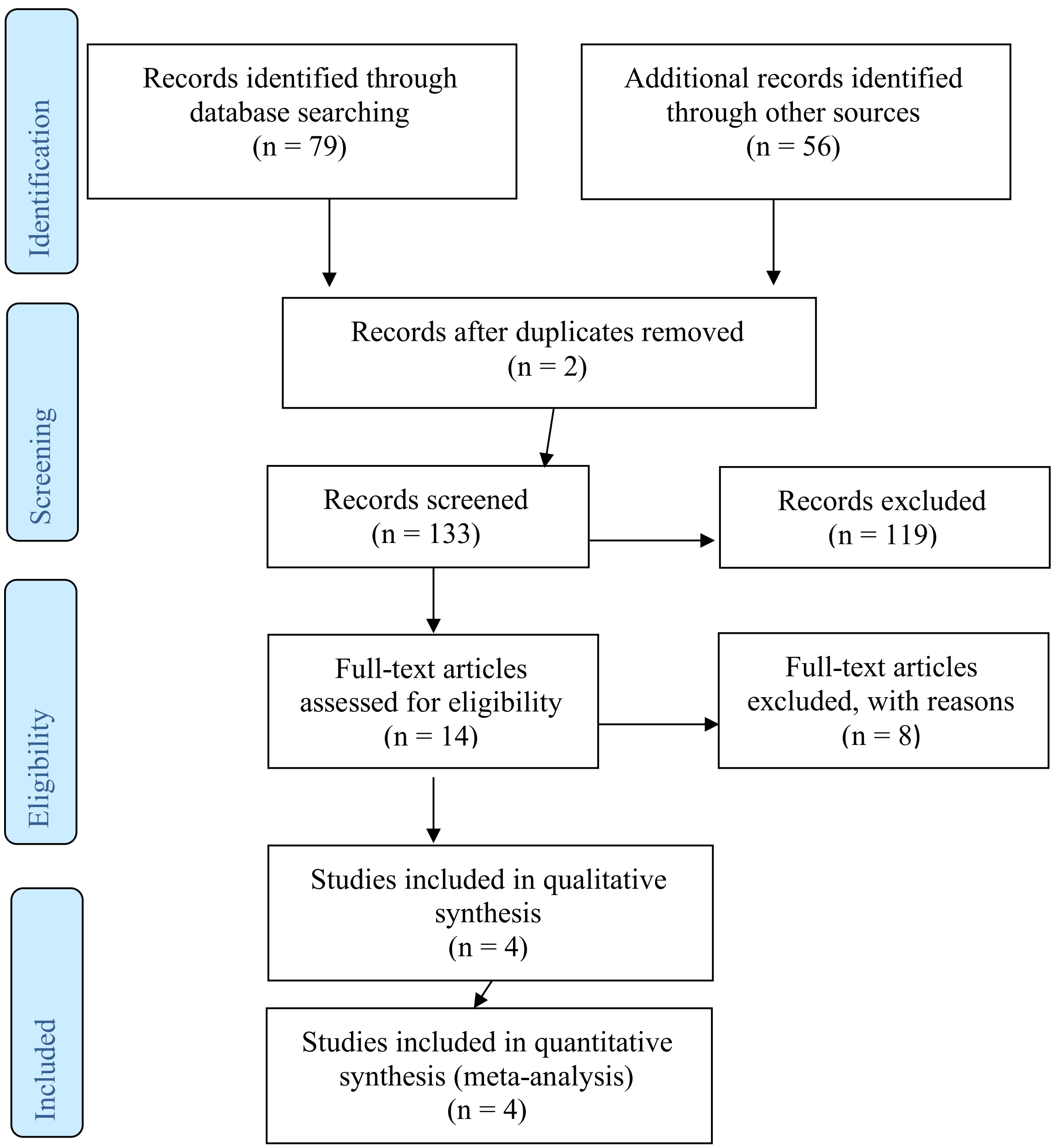

Figure 1. PRISMA Flow Diagram

Using the PRISMA four-phase diagram (Appendix B), 79 results were identified through database searches. 56 results were obtained via citations for a total of 135 results identified. After being screened for duplicates, 133 were left. The 133 results were screened for eligibility and 119 were excluded. The abstracts and titles were assessed for inclusion and exclusion criteria specific to this systematic review and assessed as being appropriate studies. The remaining 14 full text studies were further assessed for eligibility, which resulted in 4 quantitative or qualitative studies which addressed communication and teamwork and were examined as a result. The PRISMA four-phase diagram helped determine these articles were appropriate for this systematic review (Moher et al., 2009).

Significant information was extracted and recorded into the data collection tables in Appendix C. Lastly, the studies were summarized in a cross-study analysis to determine if the intervention had an influence on the outcome (Appendix D).

Chu-Weininger et al., (2010) (Appendix C1) conducted a quantitative survey to measure teamwork and safety climate in three ICUs in a healthcare system before implementation of remote monitoring by an intensivist using eICU technology. Other ICUs in the system were not used because they had implemented the tele-ICU prior to the study beginning. The study included a six-bed medical ICU in a non-teaching community hospital, a 14-bed surgical ICU in a non-teaching community hospital and 20 bed shock trauma ICU tertiary care teaching hospital. The survey included a six-item Teamwork Climate Scale (TWS) and included eight additional teamwork items. The TWS scale was taken from the Safety Attitudes Questionnaire which was psychometrically validated. The eight additional items were used because of the information they prompted.

118 surveys pre-tele-ICU and 118 post tele-ICU surveys were distributed to RNs and providers. The rate of response was 71% and 60% correspondingly. This produced a sample size of 84 pre-survey and 71 post survey. The participants were mostly white female, registered nurses who had 3-12 years of critical care experience. The study found implementation of a tele-ICU correlated with enhanced teamwork in some of the units that were being observed. It was also identified that nurses and providers in the monitored ICUs had an increased level of confidence that their patients were effectively covered when they were off the unit. Nurses also felt that it was easier to contact physicians and that it also limited interruptions. There was significantly greater improvement in the TWS scores in the post tele-ICU nurses compared to that of physicians. This is likely associated with the fact that nurses are the end users in the system. They received the most interruptions and interacted with the tele-ICU team the most.

Chu-Weininger et al., (2010) reported being surprised by how quickly that the teamwork climate improved after deployment of the tele-ICU. Particularly the TWS scores that addressed speaking up, getting help and asking questions. The eICU can assist with these critical communication events specially since they are available for consultation to the nurses 24 hours a day.

There are limitations to this study. First, the results may not be generalizable to other types of ICUs or to hospital systems that use or apply this technology differently. Second, the ability to reproduce these findings is impacted by each of the ICUs leadership styles and abilities. The cohesiveness of each ICU as a team prior the initiation this technology would affect variations in teamwork outcomes. Finally, the data produced in this study is limited by the statistical power of a small sample. More research is needed to determine if teamwork improves acceptance and perceived use.

Hoonakker et al., (2017) looked at how tele-ICU nurse attributes and organizational characteristics impact tele-ICU nurses' satisfaction and trust of the monitored bedside ICU and if these features are affected by communication. Organizational characteristics were collected for five tele-ICUs and the ICUs they monitored. A questionnaire was distributed to 110 tele-ICU nurses which addressed trust, satisfaction, nurse characteristics, and perceived communication with bedside ICU nurses. The nurse characteristics collected were work-specific data (whether the nurse has worked in an ICU that the tele-ICU monitors, number of years of experience working in an ICU, hours work per week), and personal data (age, level of education). Tele-ICU nurses' assessment of communication between the tele-ICU nurse bedside ICU nurses in 3 randomly selected ICUs they monitor which compiled a total of 321 assessments about their communication between the nurses in the ICU and the tele-ICUs nurses were also gathered. Information about nurses' satisfaction and trust of the bedside ICU nurses they monitor was collected and rated on a scale of 1-10.

Communication measures consist of 9-items that were categorized into three scales: communication timeliness, communication openness, and communication inaccuracy. The communication measures were recoded to correlate to values between 0 and 100. These measures were taken from Shortell and colleagues' questionnaire (Shortell et al., 1991) and shortened and analyzed to ensure valid and reliable results.

Data from the tele-ICU nurses' questionnaire, the monitored ICUs characteristics, and the tele-ICUs characteristics resulted in a two tiered path model to analyze the collected data. The communication measures: communication timeliness, communication openness, and communication inaccuracy were used as mediators in the model to evaluate whether communication mediates satisfaction and trust.

This study found that all of communication measures (openness, inaccuracy, and timeliness related to the tele-ICU nurses' satisfaction or trust on the ICUs they monitored. Communication openness was significantly linked to both satisfaction ($p<0.001$) and trust ($p<0.01$). Communication inaccuracy was notably associated with less trust of monitored ICUs ($p<0.001$). Finally, communication timeliness was substantially associated with satisfaction of monitored ICUs ($p<0.05$).

The results of the study showed that almost all of relationships between the organizational factors and satisfaction are mediated by communication but there are also some direct effects of organizational factors on trust such as numbers of hours worked in the eICU, age, and tenure. In general, nurses aged 55 or older and/or nurses that have more years of tenure are typical less satisfied and express less trust with the ICUs they monitor. Lastly whether the eICU nurse has worked or currently works in the ICU that is monitored is positively related to communication openness and timeliness and negatively related to communication inaccuracy.

Mullen-fortino and colleagues in 2012 completed a study that sought to identify information about the perceptions of nurses towards telemedicine and potential approaches to improve communication between the eICU team and bedside nurses. They performed a cross sectional study of two independently managed hospitals with a total of

3 ICUs which use an eICU program. The internet-based survey was administered to actively practicing nurses in the 3 units. The survey tool was based on a pilot study where semi structured interviews from 28 nurses at each of the three hospitals. The survey was anonymously dispensed via email. Survey questions included domains of functionality, patient and family outcomes, privacy, and organizational climate. Nurses who reported not working any night shifts were directed to the end of the survey because they had limited or no contact with the eICU component. Incentives were provided in the form a random lottery for two $100 gifts cards. Responses were collected as Likert-scaled responses ranging from 1 to 5 or categorical responses. The survey was sent to 179 nurses. A total response of 93 nurses completed the survey, yielding a response rate of 52%. 72 respondents worked at least 1 night shift and had experience with the eICU. 44 % of respondents regularly incorporated interventions suggested by eICU staff. Only 11% felt that the eICU was intrusive. Respondents generally reported infrequent contact with the eICU. 31 % stated that they had less than 3 contacts with the eICU in the preceding six months. Contact with eICU was less than anticipated. 72% of respondents thought that telemedicine increases patient survival. 47% nurses thought that telemedicine prevented medical errors. Only 9% of nurses surveyed thought that the eICU disrupted workflow. Responses between the two hospitals included in the study were similar. Identified limitations to the study were: the study consisted of 93 respondents, eleven of them excluded for lack of contact with the eICU. The three units surveyed used the same eICU hub, therefore results could not be generalized.

Moecki and colleagues in 2013 completed a study to identify factors that were associated with ICU staff acceptance of an eICU program in both the preimplantation and postimplementation phases. Both clinicians and administrators participated in this qualitative study. Observations, individual and group interviews were conducted to explore changes in participants expectations, perceptions, and attitudes towards using eICU technology. The study was conducted in the Veterans Health Administration's VA Midwest Healthcare Network which included eight ICUs in seven different facilities. 97 participants took part in the semi structured group and individual interviews, of which 32% participated in both preimplementation and postimplementation interviews. Interviews were conducted one to three weeks before implementation and six to twelve weeks after implementation. Interview guides were developed to produce participants responses regarding changes that potentially impacted patient care, safety, teamwork, work & communication flow, and work design. These themes were also the focus of 37 hours of observational data during the postimplementation phase which was used to confirm interview data.

Four factors were identified prior to the implementation of eICU technology that influenced acceptance of use: training, understanding & expectations, perceived need, and organizational factors. One excerpted comment from a nurse stated that "it is difficult to extend expectation of responsibility to an unfamiliar team where the relationships of trust has yet to be established". Another staff member questioned how the eICU team would help since that ICU has plenty of access to physicians and experienced teams in their facility.

Facilitators of acceptance was largely completed through site visits by nurses of the eICU team. According to one eICU coordinator, eICU nurses meeting with bedsides ICU nurses about the eICU fostered buy-in for the staff as well as basic operational information about how it is used and what the capability of the technology is. Site visits were used to counter the discomfort of being monitored, humanized the eICU team and allowed the foundation of thought that the eICU can and should be looked at as coworkers, working towards the same goal, caring for the patient.

Post implementation interviews yielded four factors influencing staff acceptance which shifted as result in the implementation of eICU program. These post implementation factors were understanding and expectations, the work system, perceived usefulness, and relationships. Barriers to the perceived need remained low during the first few months after implementation. At academically affiliated ICUs, the use of the eICU as an extra layers of support during off hour shifts were minimal. Working within established communication configurations was a barrier to residents using the eICU. A resident reported opting to keep the collected team informed and included them in the decision making rather contacting the eICU. A fellow reported that it threatened resident education and autonomy. The impeding of extra communication was not just limited to managing critical situations with the eICU team. Other forms of communication were also seen as burdensome to bedside ICU nurses. For example, changes in the timing & content of charting. These changes were necessary because the eICU nurses were dependent on pertinent & timely charting to support their tasks.

Even with barriers to acceptance, early signs of adoption were identified. Both nurses & physicians acknowledged that the eICUs staff extensive access to patient data accompanied with the ability to step back from the urgency of the bedside environment provided an aspect of clinical practice that was distinct and compatible. Team building and incorporating relationships were evident early on in implementation. Efforts to incorporate the support center into a new hybrid team which combined the bedside ICU team along with the eICU staff were initiated by early adopters.

While perceived need was firmly associated with acceptance before the implementation of the eICU, once it became active this acceptance shifted to whether staff found it useful. The findings of this study suggests that eICUs mat improve perceived usefulness by recognizing and supporting the range of needs different types of ICUs have and seeking out and addressing feedback to ensure that these are met. Underpinning most of the themes in this study is the effect of how the relationships of virtual teams' function in the critical care setting. Even though eICU leadership and staff invested in relationship development and prior to implementation, a comprehensive method which focuses on establishing and maintaining individual, organizational, and technological trust through teamwork before and after implementation of an eICU program. Addressing needs both in the eICU as well as in the bedside ICU is critical. This may foster early adoption along driving sustainment.

Several limitations were noted in this study. First, the study was a descriptive study of only one eICU program within one single healthcare system. A comparative report studying another eICU program may identify other barrier & facilitators. Adding to this limitation is that the VA has a strong culture of quality improvement dedicated towards benchmarking ICU outcomes. Which may not exist in other health care systems. Another limitation is the lack of diversity in professions that were included in the sample. The inclusion in more residents, fellows, hospitalists, and ICU staff physicians would provide more insight into the barriers and facilitators affecting physician acceptance and perceived use. Finally, though the findings were based on self-descriptions of staff experiences and perceptions of the eICU, which were corroborated by observable data, other data external to participants reported perceptions were not used to validate their impact on staff acceptance or intention to use.

Summary and Conclusions

eICU technology can dramatically improve clinical outcomes and transform critical care delivery across healthcare systems. A thorough literature review was conducted to highlight the importance and potential of this technology. Principles of effective teamwork and communication are central to facilitating successful uptake/implementation of eICU technology. Healthcare today is delivered by multidisciplinary teams as opposed to individuals. Changes in healthcare delivery have not been supported by modifications in the systems for communication between health professionals, especially across healthcare disciplines (Weller et al., 2014). To achieve optimal functioning teams, members must respect and trust each other to give and receive feedback. Forming mutually continuing education plans which focuses on cultural mindfulness and communication is especially important. Shared acknowledgement for team members role and responsibilities must occur for collaboration to take place (Wilkes et al., 2016). The productive incorporation of the eICU team into the care team requires the collaboration of goals, respect, and knowledge (Canfield & Galvin, 2018).

Acceptance of information technology is “the demonstrable willingness of a user group to employ information technology for the tasks it is designed to support” (Rufo, 2012). Acceptance goes beyond just the agreement to use specific technology; it requires verification of usage to perform tasks and realization of outcomes proposed by the creators of that technology. The acceptance of eICU technology by clinical staff is essential for both financial and clinical outcomes (Udeh et al., 2018).

The purpose of this project was to conduct a systematic review to examine whether communication and teamwork have any effect on the acceptance and perceived use of eICU technology. A literature search was conducted using the search engines PubMed, Ovid, Medline and CINAHL. The PRISMA checklist and flow diagram was utilized to demonstrate the selection process for study inclusion. After development of inclusion and exclusion criteria, a total of four studies were selected as meeting criteria for inclusion in this systematic review. Each study was thoroughly evaluated to allow extraction of relevant data for summarization in data collection tables.

Chu-Weininger et al., (2010) found that teamwork improved over time after the implementation of eICU program. Improved communication was also fostered by the eICU which provided a climate of "speaking up" and a forum for getting help and asking questions. Hoonakker et al., (2017) found that openness to and accuracy of communication improved teamwork between eICU and staff. Mullen-fortino et al., (2012) found that there is a high importance of knowing the provider in the eICU and that the bedside nurses are more likely to contact the eICU when they know the provider personally. Moecki et al., (2013) study of pre-implementation and post-implementation of an eICU program found that prior to implementation most staff surveyed knew little about the eICU program. The need for understanding, training and support were identified as influencers prior to implementation which has a direct correlation to perceived need. Post implementation influencers of relationship acceptance (Teamwork), utilization and understanding (communication) also correlated with ongoing perceived usefulness.

The articles reviewed for this study demonstrate the importance of teamwork and communication in successful implementation of an eICU. eICUs represent a major investment. Equally important to investment in technology is investment in the development of staff in the areas of teamwork and communication necessary to foster successful uptake of eICU technology. When the launch of eICU is appropriately supported, it may increase success of the program. Further research is needed to evaluate subsequent and related outcomes at the patient and system levels.

Next, the recommendations and implications for advanced nursing practice will be discussed.

Recommendations and Implications for Advanced Nursing Practice

The emergence of eICU technology was in large part developed as a response to the shortage of intensivists and the high-cost of 24/7 intensivist coverage. The APRN, and more specifically, the clinical nurse specialist (CNS) is uniquely positioned to lead eICU practice. The goal of the eICU is to ultimately improve quality and safety by leveraging technology that uses data and information, funneled through predictive algorithms to help triage, and prioritize patients and identify the need for earlier interventions.

The eICU intersects at the nurse, patient and systems level and the CNS is uniquely prepared to function across these sphere of impact. In this role the CNS will be able to develop critical orientation programs which focus on communication and development of collaborative team relationships which often are neglected. The CNS is positioned the help with the development of communication and teamwork both with the bedside ICU nurses as well as the eICU nurses behind the monitoring.

Monitoring outcomes as it pertains communication skills and interactions of the collaborating professionals will potentially affect the success of eICU programs. The CNS will be able to identify potential communication gaps and other areas that will need to be addressed to ensure the best possibility for success of these complicated, expensive yet critical and profound programs. The CNS uses a wide lens viewpoint to see and manage system level problems and to utilize potential successes. The CNS is uniquely prepared to function at the advanced level across the nurse, patient, and system spheres, with a focus on driving optimal patient outcomes. Relative to the eICU, the CNS is prepared to assess system and patient level outcomes in relation to the quality of communication and collaboration, and design and implement programs that optimize outcomes at all levels. Because of the knowledge in quality and improvement, the CNS will be able to focus on more mid-range and long-range goals such as sustainment for eICUs programs which have already been developed. The CNS is keenly aware that without sustainment, eICU programs, like all other newly implemented programs, will falter. The CNS will be able ensure the sustainment remains a top priority

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Appendix A

PRISMA 27 Item checklist:

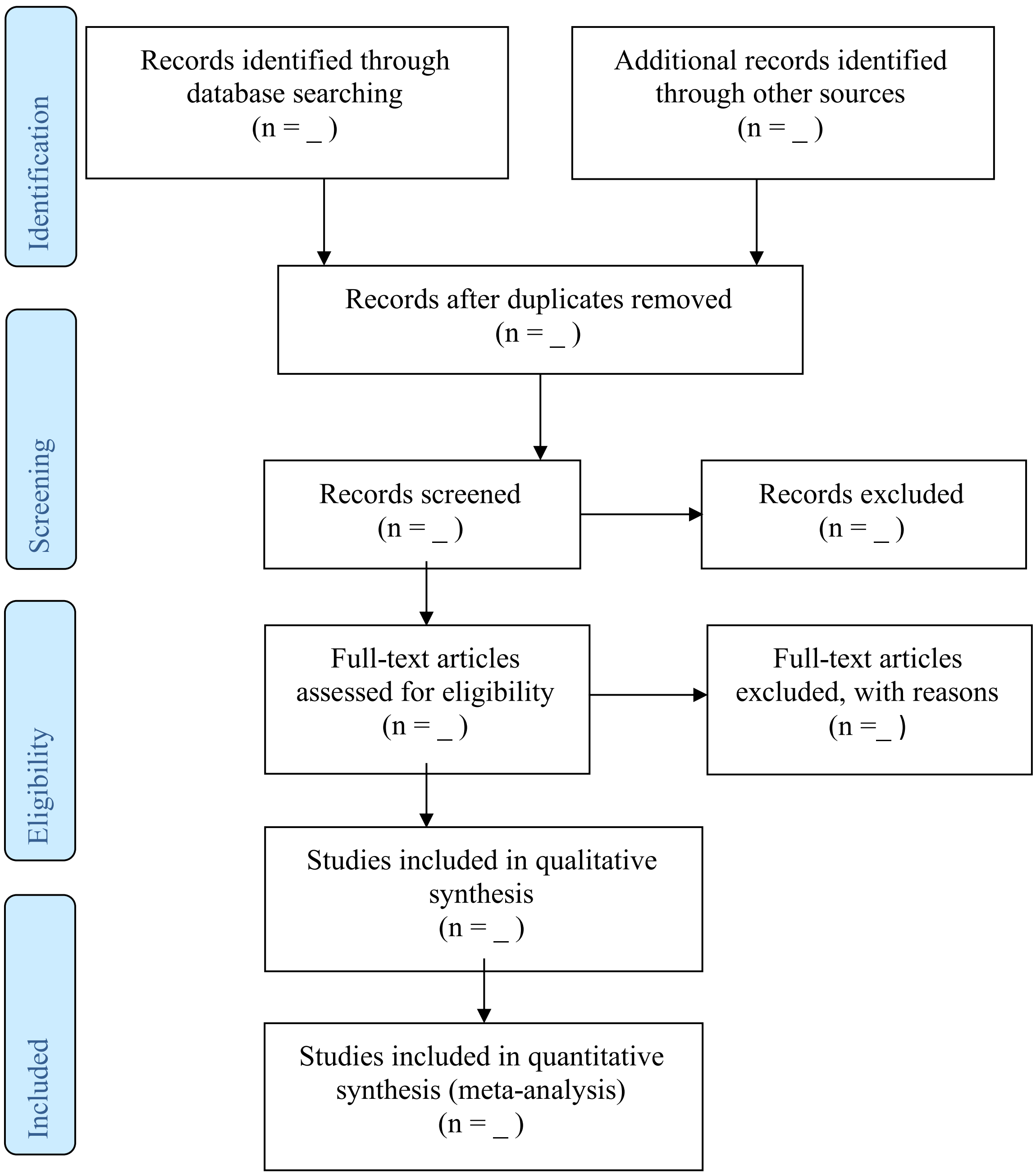
Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

(Moher et al., 2009)

Appendix B

PRISMA 2009 Flow Diagram



(Moher et al., 2009)

Appendix C

Data Extraction Tables

Table C1 - Chu-Weininger, M. L., Wueste, L., Lucke, J. F., Weavind, L., & Mazabob, J. (2010). The impact of tele-ICU on provider attitudes about teamwork and safety climate. *Quality and Safety in Health Care*, *19*, e39. https://doi.org/10.1136/qshc.2007.024992

Site/Sample	Method/Design	Communication Measures	Teamwork Assessment	Limitations
Pre-implementation stage: nurses (n = 61), other healthcare professionals (n = 23) Post-implementation nurses (n = 51), other healthcare professionals (n = 19)	Controlled pre tele-ICU and post tele-ICU- cross-sectional survey Survey instruments consisted of a 6-item teamwork climate survey, a 7-item safety climate survey and other survey items related to tele-ICU which were taken from the validated Safety Attitudes Survey	Teamwork Climate Scale (TWS) Safety Climate Score (SCS) and	Teamwork Climate Scale (TWS) Safety Climate Score (SCS) and Mean teamwork climate score was 69.7 (25.3) and 78.8 (17.2), pre and post tele-ICU (p¼0.009) The mean SCS score was 66.4 (24.6) and 73.4 (18.5), pre and post tele-ICU (p¼0.045) SCS scores within each ICU improved overall SCS scores for these hospitals decreased from 69.0 to 65.4	Small sample size Study conducted during various stages of implementation across the system Study did not explore long-term, post-implementation results.

Table C2 - Hoonakker, P. L., Pecanac, K. E., Brown, R. L., & Carayon, P. (2017). Virtual collaboration, satisfaction, and trust between nurses in the tele-ICU and ICUs: Results of a multi-level analysis. *Journal of Critical Care*, *2*(37), 224–229. https://doi.org/10.1016/j.jcrc.2016.10.018

Site/Sample	Method/Design	Communication Measures	Teamwork Assessment	Limitations
Five large tele-ICUs: 2 on the East coast, 2 in the Midwest and 1 on the West coast Tele-ICU nurses (n = 110) return the questionnaire with a response rate of 84%	Cross-sectional survey Data of tele-ICU characteristics and characteristics of the ICUs they monitored were collected at 5 tele-ICUs located throughout the country. 110 nurses at sites filled out questionnaire containing items related to their characteristics and their trust, satisfaction, and perceived communication with monitored bedside nurses. Data analyzed using a hierarchical path model, with communication variables entered as mediators.	Questionnaire was developed specific for nurses in the tele-ICU. Included were personal information- age & level of education and work-related information-hours worked per week and whether they work or has worked in an ICU that the tele-ICU monitors, and years of experience working as a nurse in an ICU Trust & satisfaction of the bedside ICU nurse they monitor was rated on a scale of 1-10. Assessment of communication on a scale of 1-5 with bedsides nurses they monitor which resulted in 321 assessment of communication between the tele-ICU nurse and the bedside ICU nurse 9 communication measure grouped into 3 scales: (1) communication openness, (2) communication timeliness, (3) communication inaccuracy. Scale measures were coded to values 0-100	Communication openness mediated the relationships of both working at a monitored ICU and being older (≥55) on satisfaction. Communication accuracy mediated the relationships of both a specialized monitored ICU and working at a monitored ICU on trust	Evaluation limited to perceptions of eICU nurses. Perception of bedside nurses was not included. Nurses surveyed only evaluated three ICUs, though may have monitored patients in more than three ICUs. However, ICUs evaluated were randomly assigned.

Table C3 - Mullen-fortino, M., Dimartino, J., Entrikin, L., Mulliner, S., Hanson, C. W., & Kahn, J. M. (2012). Bedside nurses' perceptions of intensive care unit telemedicine. *American Journal of Critical Care*, *21*(1), 24–31. https://doi.org/10.4037/ajcc2012801

Site/Sample	Method/Design	Communication Measures	Teamwork Assessment	Limitations
Beside nurses surveyed (N = 179) response rate 52% (n = 93) Setting: Three ICUs within two academic medical centers in northeast region eICU support was provided for bedside staff on night shifts only.	Cross-sectional online survey regarding practices and perceptions of telemedicine. Survey developed based on preliminary qualitative study. Survey validity was established via pilot survey. Survey administered anonymously Nurses who reported not working any night shifts were directed to the end of the survey and did not answer any study questions	Survey included questions across the domains of functionality, patient and family outcomes, privacy, and organizational climate. Responses were collected as either categorical or Likert-scale responses. 44% reported regularly incorporating interventions suggested by the telemedicine staff. Only a small minority felt that telemedicine was intrusive (11%) Responses were similar between two hospitals. Contact with telemedicine staff was less than anticipated.	93 respondents (response rate, 52%) 72 worked at least 1 night shift, had experience with the telemedicine unit. Reported contact with the tel-ICU infrequent: 31% reported being called by the unit 3 or more times in the preceding 6 months. (72%) thought that telemedicine increases patients' survival (47%) thought telemedicine prevents medical errors Only a small minority felt that telemedicine	Although there were 93 total respondents, 11 did not have any night shift experience and were excluded from the study. Abstract states that intensivists and nurses were surveyed; however, results reported only from nurses. Small sample size Study limited to two hospitals supported by a single eICU.

			interrupted workflow (9%) Nurses thought that personally knowing the telemedicine physician was important (79%) Nurses were more likely to contact the telemedicine if they knew the physician on call (61%)	

Table C4 - Moeckli, J., Cram, P., & Cunningham, C. (2013). Staff acceptance of a telemedicine intensive care unit program: A qualitative study. *Journal of Critical Care*, *28*, 890–901. https://doi.org/10.1016/j.jcrc/2013.05.008

Site/Sample	Method/Design	Communication Measures	Teamwork Assessment	Limitations
Setting: VA Midwest Healthcare Network Tele ICU. Includes 8 ICUs across 7 facilities. Pre-implementation stage: Nurses (n = 40) Others (n = 26) Post-implementation stage: Nurses (n = 42) Others (n = 20)	Qualitative interview and site observation Network Tele-ICU and affiliated ICUs. A qualitative content analysis of pre-implementation and postimplementation transcripts and field notes was undertaken to identify themes positively and negatively influencing Tele-ICU acceptance.	Despite communication and outreach most participants reported that they knew very little about the tele ICU. Related to communications, Telemedicine ICU training, understanding and perceived need were important factors influencing pre-implementation, and Tele ICU understanding, perceived usefulness and relationships acceptance were important factors influencing post implementation. Confusion about how to use the tele-ICU and disruptions in	4 factors Emerged as influencing acceptance before implementation: 1.) Telemedicine ICU training 2.) Tele-ICU understanding 3.) Perceived need 4.) Organizational factors 5 factors emerged as influencing acceptance after implementation: 1.) Tele-ICU understanding 2.) impact on work systems 3.) perceived usefulness, 4.) relationships acceptance 5.) utilization. Barriers to implementation included: 1.) Confusion about how to use the Tele-ICU 2.) Disruptions to communication and workflows 3.) Unmet expectations 4.) Discomfort with being monitored Facilitators: 1.) Positive experiences	Study is limited to a single to the VA within a single geographical region. Of note, conclusion of the authors is that more investment is needed in education and training

		communication and workflows were identified as important barriers.	2.) Discovery of new benefits 3.) Recognition of Tele-ICU staff as complementing bedside care	

Appendix D

Cross study analysis table

Study	Relation of study to concepts of communication and teamwork	Key outcomes
Study 1 (Chu-Weininger et. al., 2010)	Directly measured perception of teamwork using the TWS. Also measured perceived safety using the SCS.	Demonstrated modest and improving teamwork scores over time; however, found decreasing safety scores over time.
Study 2 (Hoonakker et al., 2018)	Evaluated factors impacting trust and satisfaction of monitored bedside ICU nurses	Openness to and accuracy of communication improved teamwork between eICU and staff
Study 3 (Mullen-fortino et al., 2012)	Explored various factors including the impact of communication on teamwork	Importance of knowing the provider. Findings indicate that staff are more likely to contact a provider who they know.
Study 4 Moeckli et al., 2013)	Explored key factors including communication and teamwork related to acceptance of pre- and post-eICU implementation	Related to communications, Telemedicine ICU training, understanding and perceived need were important factors influencing pre-implementation, and Tele ICU understanding, perceived usefulness and relationships acceptance were important factors influencing post implementation. Confusion about how to use the tele-ICU and disruptions in communication and workflows were identified as important barriers.