USING DIAGNOSTIC DECISION SUPPORT SYSTEMS TO REDUCE DIAGNOSTIC ERROR:

A SURVEY OF CRITICAL CARE PHYSICIANS

Elizabeth S. Jones, MLIS

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APPROVED:

Ana Cleveland, Committee Chair
Jeonghyun Kim, Committee Member
Brandt Wiskur, Committee Member
Jiangping Chen, Committee Member and
Chair of the Department of
Information Science
Kinshuk, Dean of the College of Information
Victor Prybutok, Dean of the Toulouse
Graduate School

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The purpose of this study is to investigate the use of decisions support systems (DSS) by critical care physicians and to address the following questions: Does the use of a decision support system during diagnosis reduce diagnostic error and how are decision support systems used by critical care physicians? There are no studies that address these research questions in a clinical setting. The information assessment method (IAM) was used to guide the development of the survey questions. Critical care physicians from the University of Oklahoma Health Sciences Center were surveyed. Chi squared test for independence was used to determine the relationship between DSS use and diagnostic error rates. There were three main findings of the study: (1) use of a DSS by a critical care physician can decrease diagnostic error by up to 60%; (2) 56% of critical care physicians are using a DSS during diagnosis to learn something new, confirm something they already knew, and/or to reassure themselves; and (3) the increased use of a DSS by critical care physicians can lead to a decrease in the belief of the ability of a DSS to reduce diagnostic error.

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CHAPTER 1

INTRODUCTION

Background

In 2013 a Medical Library Association (MLA) webinar discussed preventing diagnostic error. The case of a young girl, Jessica Barnett, who eventually died after repeated misdiagnosis was explored. Jessica had fainting spells for 4 years and was continually misdiagnosed. For a time, she was diagnosed with Epilepsy. Her family thought she had Long QT Syndrome (LQTS), a heart condition. However, doctors repeatedly told her she did not, despite an electrocardiogram (ECG) that indicated Jessica had LQTS. At one point, a neurologist referred her to a cardiologist because of pressure from Jessica's family, but the neurologist told the cardiologist she did not have LQTS. The ECG performed by the cardiologist came back negative for LQTS. At age 17, Jessica died from LQTS (Barnett, n.d.). In 2014, the first case of Ebola that appeared in the United States was misdiagnosed and eventually ended in death (Carr). There are many examples which lead to questions about the frequency, causes, and reduction of diagnostic errors.

According to the Society to Improve Diagnosis in Medicine, SIDGM, (2015) misdiagnosis happens in one out of ten cases. Berner and Graber (2008) estimate a 10-15% misdiagnosis rate across specialties. The misdiagnosis rate for critical care is higher, between 17.7% (Jayaprakash et al., 2019) and 28% (Winters et al., 2012), with 5% of emergency room patient deaths resulting from diagnostic error. Balogh, Miller, and Ball (2015) estimate "…that most people will experience at least one diagnostic error in their lifetime, sometimes with devastating consequences" (p. 1). While there is not agreement on the rate of misdiagnosis, research findings show that reducing misdiagnosis should be a priority, especially in critical care/intensive care units where the rates are higher (Jayaprakash et al., 2019; Winters et al., 2012). In the literature diagnostic error has been largely ignored in relation to other medical errors (Newman-Toker & Pronovost, 2009), even though diagnostic error accounts for up to 30% of all medical errors (Schiff et al., 2005). Diagnostic errors are a source of preventable harm (Newman-Toker & Pronovost, 2009). Singh et al. (2010) found that 45% of physicians indicated that harm happened due to diagnostic error 1-2 times a year. In 2011, MacDonald conducted a survey of physicians and found that 14% of physicians felt 11%-15% of their diagnostic errors resulted in harm. While the majority of physicians felt harm was caused in less than 10% of cases with errors, one autopsy study confirmed that 8.7%-10.5% of deaths were from preventable errors (Podbregar et al., 2001). Therefore, it is important to find methods to improve diagnosis and prevent error in the diagnostic process. In order to prevent diagnostic error, we must first understand the causes of diagnostic error.

The literature points to several causes for diagnostic error, the most common being the failure to consider alternate diagnoses, which is the process of differential diagnosis (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012; Graber, Franklin, & Gordon, 2005; Schiff et al., 2009). This study seeks to further research in this regard and will focus on a solution that provides differential diagnosis. The literature on this topic is further examined as part of the literature review in Chapter 2.

Problem Statement

There is a need to reduce diagnostic error, but there are no known solutions. In fact, there is a gap in the research between the identification of potential solutions and the implementation/evaluation of these solutions (Henrickson & Brady, 2013). There is a body of research that defines and draws attention to the problem of diagnostic error (Abimanyi-Ochom et al., 2019; Graber, 2005; Graber, Franklin, & Gordon, 2005; Graber, Wachter, & Cassel, 2012; Jayaprakash et al., 2019; Makary & Daneil, 2016; Newman-Toker, 2014; Newman-Toker & Pronovost, 2009; Sing & Weingart, 2009; Singh et al., 2012; Singh, Meyer, & Thomas, 2104; Tejerina, 2012; Thammasitboon, Thammasitboon, & Singhal, 2013; Winters et al., 2012; Zwaan, Thijs, Wagner, van der Wal, & Timmermans, 2012). There are also numerous studies that look at the causes for errors made during the diagnostic process, and some have tried to identify potential solutions (Berner & Graber, 2008; Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012; Henriksen & Brady, 2013; Schiff, 2014; Schiff et al., 2005; Sibbald, de Bruin, Yu, & van Merrienboer, 2015; Singh, 2014; Singh, Schiff, Graber, Onakpoya, & Thompson, 2017). However, there is little to no literature evaluating solutions in a clinical setting (Abimanyi-Ochom et al., 2019).

Decision Support Systems (DSS) that offer differential diagnosis are a potential solution for reducing diagnostic error (Delaney & Kostopoulou, 2017; Medical Library Association, 2013). Unfortunately, most physicians only use a DSS when they already know they have a wrong diagnosis (Berner & Graber, 2008). As stated before, much of the existing research has not been conducted in a clinical setting. (Bond et al., 2012; El-Kareh, Hasan, & Schiff, 2013; Garg et al., 2005; Riches et al., 2016; Sim et al., 2001; Singh, Schiff, Graber, Onakpoya, & Thompson, 2017; Trowbridge & Weingarten, 2001). Currently, there is only one study that evaluates a DSS (UpToDate) as a solution for reducing diagnostic error in a clinical setting, and the findings indicated that diagnostic error was significantly reduced with access to this the DSS(Shimizu, Nemoto, & Tokuda, 2018).

Purpose of the Study

The purpose of this study is to fill the research gap that exists between theorized solutions to reduce diagnostic error and evaluating those solutions in a clinical setting (Abimanyi-Ochom et al., 2019; Winters et al., 2012). Several studies show one of the main causes of diagnostic error is not considering the correct diagnosis (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Allessandro, 2012; Graber, Franklin, & Gordon, 2005; Schiff et al., 2009). Decision Support Systems (DSS) offer a list of alternate diagnoses, and are recommended as potential solutions to reduce diagnostic error (Delaney & Kostopoulou, 2017; Medical Library Association, 2013).

This study will examine the use of DSS in clinical settings and their effects on diagnostic error. Additionally, the study will focus on critical care physicians using a DSS because critical care units experience the highest rates of diagnostic error (Jayaprakash et al., 2019; Winters et al., 2012).

Definitions

- *Clinical decision support systems (CDSS)*: A CDSS is any system that helps healthcare professionals with decision-making in a clinical setting (Garg et al., 2005; Musen, Shahar, & Shortliffe, 2006).
- *Critical care*: The U.S. National Library of Medicine's (2015) Medical Subject Headings define critical care as "[h]ealth care provided to a critically ill patient during a medical

emergency or crisis" ("Critical Care") and also indicates the term intensive care can be used. The terms critical care and intensive care can be used interchangeably. Moving forward the term critical care will be used.

- *Critically ill*: Both definitions for intensive and critical care include the term "critically ill." The Society of Critical Care Medicine (2015) indicates that critical care is needed when a patient has a life-threatening condition, indicating critically ill equates to life-threatening.

- *Curiosity*: Merriam-Webster (2012a) defines curiosity as an "…interest leading to inquiry" (para. 1) For the purpose of this paper curiosity is referring to the interest that leads physicians to use a DSS.

- *Decision support systems (DSS)*: Some researchers use the terms CDSS and differential diagnostic generator interchangeably. Despite Bond et al. (2012) referring to the Isabel system as a differential diagnostic generator, Graber and Mathew (2008) refer to Isabel as a CDSS. CDSS and differential diagnostic generators are also referred to as DSS (Bond et. al, 2012; Trowbridge & Weingarten, 2001). DSS seems to be the broader term to refer to both types of systems. These systems all provide diagnostic information. For the purpose of this study they will be referred to generically as decision support systems (DSS).

- *Diagnostic error*: Balogh, Miller, and Ball (2015) define diagnostic error as a failure to form an accurate account of the health problem in question, but also point out there is no agreement concerning the definition of diagnostic error. Several articles describe diagnostic error as missed, delayed, or wrong diagnosis (Graber, 2005; Graber, Franklin, & Gordon, 2005; Newman-Toker & Provonost, 2009; Schiff et al., 2009). However, Newman-Toker (2014) note that "…thought leaders now generally agree there is probably little value to insisting on subdividing incorrect diagnosis labels as specifically ‘delayed’, ‘missed’, or ‘wrong’” (p. 44). Therefore, this paper will use the diagnostic error definition from Thammasitboon, Thammasitboon, and Singhal (2013) which is simply an incorrect (wrong) diagnosis.

- *Differential diagnosis (DDX)*: According to Black’s Medical Dictionary differential diagnosis is a set of potential diagnoses for a given patient’s health condition, and analysis allows for choosing the correct diagnosis from the set (Marcovitch, 2010). Merriam-Webster (2016b) further specifies the set of diagnoses have similar symptoms and the process for choosing the correct diagnosis is differential diagnosis.

- *Differential diagnostic generator*: Bond et al. (2012) define a differential diagnostic generator as a CDSS that generates a differential diagnosis “…based on a minimum of two items of patient data” (p. 214).

- *Effect*: According to the Cambridge Dictionary of Statistics, effect is “used for the change in a response variable produced by a change in one or more explanatory or factor variables” (Everitt & Skrondal, 2010, p. 148). For the purposes of this study the term effect is used to indicate a change in any research variable.

- *Exchange information*: Merriam-Webster (2012d) defines communication as “…a process by which information is exchanged” (para. 1). Merriam-Webster (2012e) also defines exchange as a trade. For the purposes of this paper the phrase exchange information will be used to refer to physicians communicating with other physicians and in the process trade information about a patient’s diagnosis or care.

- *Factor*: Merriam-Webster (2016c) defines factor as something responsible for a result. For this study the term factor is used to refer to any research variable that is potentially responsible for a result in another research variable.

- *Forgotten*: Merriam-Webster (2012b) defines forget as being incapable of remembering or recalling something. For the purpose of the study the term forgotten (present perfect tense of forget) will be used to refer to information a physician is incapable of remembering.

- *Intensive care*: The American association of Critical-Care Nurses uses the term intensive care units (ICU) and indicates that ICUs are for the critically ill (American Association of Critical Care Nurses, 2015).

- *Intensivist*: The American College of Physicians (2017) defines an intensivist as a critical care specialist or a physician who has been certified as a critical care specialist. Thus, an intensivist could also be referred to as a critical care physician. The latter term will be used from this point forward.

- *Misdiagnosis*: Newman-Toker and Provonost (2009) define diagnostic error as delayed, missed, or wrong and then refer to these designations as misdiagnosis. Schiff et al. (2005) and Merriam-Webster (2016a) also refer to misdiagnosis as a wrong diagnosis. Other researchers use the term misdiagnosis interchangeably with diagnostic error without specifically defining misdiagnosis (Croskerry, 2009; Singh, Meyer, & Thomas, 2014). This paper considers the terms misdiagnosis and diagnostic error to be interchangeable, and for the remainder of this paper will use the term diagnostic error.

- *Share information*: One of Merriam-Webster (2012c) definitions for share is telling others something. For the purposes of the paper the phrase share information will be used to refer to physicians telling the patient something about their diagnosis or care.

Significance of the Study

This study has the potential to impact the medical, library science, and information science fields. The medical field will have more insight into whether DSS should be utilized more often during diagnosis. Professionals in the library and information science fields will be able to make better decisions on providing DSS to physicians, as well as what training may be needed to accurately make use of the DSS. Finally, the study will impact diagnostic error researchers. If the study indicates that DSS are useful in improving isdiagnosis, then the reasons why DSS are not being used can direct future research aimed at encouraging use.

Research Questions

This study is based on research that suggests diagnostic error can be reduced by considering alternate diagnoses (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012, Graber, Franklin, & Gordon, 2005; Schiff et al., 2009) and the fact that decision support systems (DSS) generate alternate diagnoses. However, research shows that physicians in general are only using a DSS when they know they have the incorrect diagnosis (Berner & Graber, 2008; Singh, Schiff, Graber, Onakpoya, & Thompson, 2017). Additionally, many hospitals now have teams of physicians that staff critical care units, and physicians with critical care specialties may treat patients outside of the critical care unit. These findings guide the following research questions and hypotheses below. The hypotheses are stated as a series of alternate (H_1) hypotheses, with an assumed relationship between variables, and null hypotheses (H_0), with no relationship between variables.

1. Does the use of a decision support system during diagnosis reduce diagnostic error?
   A. What effect does the use of decision support systems during the diagnostic process by critical care physicians have on diagnostic error?

1Ai.H_1: The use of a decision support system by critical care physicians for diagnostic purposes is a factor in occurrence of diagnostic error.

1Ai.H_0: The use of a decision support system by critical care physicians for diagnostic purposes is not a factor in occurrence of diagnostic error.

B. How does critical care physician attributes (medical credentials, type of specialty, and time practicing medicine) impact diagnostic error?

1Bi.H_1: The type of medical credentials is a factor in the occurrence of diagnostic error.

1Bi.H_0: The type of medical credentials is not a factor in the occurrence of diagnostic error.

1Bii.H_1: Having an internal critical care specialty is a factor in the occurrence of diagnostic error.

1Bii.H_0: Having an internal critical care specialty is not a factor in the occurrence of diagnostic error.

1Biii.H_1: Having a pediatrics critical care specialty is a factor in the occurrence of diagnostic error.

1Biii.H_0: Having a pediatrics critical care specialty is not a factor in the occurrence of diagnostic error.

1Biv.H_1: Having a pulmonary critical care specialty is a factor in the occurrence of diagnostic error.

1Biv.H_0: Having a pulmonary critical care specialty is not a factor in the occurrence of diagnostic error.

1Bv.H_1: Having a surgical critical care specialty is a factor in the occurrence of diagnostic error.

1Bv.H_0: Having a surgical critical care specialty is not a factor in the occurrence of diagnostic error.

1Bvi.H_1: Having an anesthesiology critical care specialty is a factor in the occurrence of diagnostic error.

1Bvi.H_0: Having an anesthesiology critical care specialty is not a factor in the occurrence of diagnostic error.

1Bvii.H_1: The amount of time a physician has practiced medicine is a factor in the occurrence of diagnostic error.

1Bvii.H_0: The amount of time a physician has practiced medicine is not a factor in the occurrence of diagnostic error.

C. Is the relevance of information provided by the DSS a factor in the occurrence of diagnostic error?

1Ci.H_1: The relevance of information provided by the DSS is a factor in the occurrence of diagnostic error.

1Ci.H_0: The relevance of information provided by the DSS is not a factor in the occurrence of diagnostic error.

2. How are decision support systems used by critical care physicians?

   A. For what purposes are critical care physicians using a DSS?

2Ai.H_1: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is a factor in the occurrence of diagnostic error.

2Ai.H_0: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is not a factor in the occurrence of diagnostic error.

2Aii.H_1: Critical care physician use of a DSS to fulfill a personal educational objective is a factor in the occurrence of diagnostic error.

2Aii.H_0: Critical care physician use of a DSS to fulfill a personal educational objective is not a factor in the occurrence of diagnostic error.

2Aiii.H_1: Critical care physician use of a DSS to satisfy curiosity or for personal interest is a factor in the occurrence of diagnostic error.

2Aiii.H_0: Critical care physician use of a DSS to satisfy curiosity or for personal interest is not a factor in the occurrence of diagnostic error.

2Aiv.H_1: Critical care physician use of a DSS to look up something forgotten is a factor in the occurrence of diagnostic error.

2Aiv.H_0: Critical care physician use of a DSS to look up something forgotten is not a factor in the occurrence of diagnostic error.

2Av.H_1: Critical care physician use of a DSS to share information with a patient, their family, or home health aides is a factor in the occurrence of diagnostic error.

2Av.H_0: Critical care physician use of a DSS to share information with a patient, their family, or home health aides is not a factor in the occurrence of diagnostic error.

2Avi.H_1: Critical care physician use of a DSS to exchange information with other health professionals is a factor in the occurrence of diagnostic error.

2Avi.H_0: Critical care physician use of a DSS to exchange information with other health professionals is not a factor in the occurrence of diagnostic error.

   B. How often are critical care physicians using a DSS?

2Bi.H_1: The frequency of critical care physicians use of a DSS is a factor in the occurrence of diagnostic error.

2Bi.H_0: The frequency of critical care physicians use of a DSS is not a factor in the occurrence of diagnostic error.

C. What type of patients do critical care physicians use DSS to diagnose; critically ill or non-critically ill patients?

2Ci.H_1: The use of DSS by critical care physicians with critically ill patients is a factor in the occurrence of diagnostic error.

2Ci.H_0: The use of DSS by critical care physicians with critically ill patients is not a factor in the occurrence of diagnostic error.

2Cii.H_1: The use of DSS by critical care physicians with non-critically ill patients is a factor in the occurrence of diagnostic error.

2Cii.H_0: The use of DSS by critical care physicians with non-critically ill patients is not a factor in the occurrence of diagnostic error.

D. The outcome of DSS information obtained by critical care physicians may change their practice. How do these changes impact diagnostic error?

2Di.H_1: Physicians practice changed or improved from use of DSS information is a factor in the occurrence of diagnostic error.

2Di.H_0: Physicians practice changed or improved from use of DSS information is not a factor in the occurrence of diagnostic error.

2Dii.H_1: Learning something new from the DSS information is a factor in the occurrence of diagnostic error.

2Dii.H_0: Learning something new from the DSS information is not a factor in the occurrence of diagnostic error.

2Diii.H_1: Confirming correct actions with the DSS information is a factor in the occurrence of diagnostic error.

2Diii.H_0: Confirming correct actions with the DSS information is not a factor in the occurrence of diagnostic error.

2Div.H_1: Being reassured by the DSS information is a factor in the occurrence of diagnostic error.

2Div.H_0: Being reassured by the DSS information is not a factor in the occurrence of diagnostic error.

2Dv.H_1: Being reminded of something already known by the DSS information is a factor in the occurrence of diagnostic error.

2Dv.H_0: Being reminded of something already known by the DSS information is not a factor in the occurrence of diagnostic error.

2Dvi.H_1: Being dissatisfied with the DSS information is a factor in the occurrence of diagnostic error.

2Dvi.H_0: Being dissatisfied with the DSS information is not a factor in the occurrence of diagnostic error.

2Dvii.H_1: Having an issue with the way information is presented in the DSS is a factor in the occurrence of diagnostic error.

2Dvii.H_0: Having an issue with the way information is presented in the DSS is not a factor in the occurrence of diagnostic error.

2Dviii.H_1: Disagreeing with information in the DSS is a factor in the occurrence of diagnostic error.

2Dviii.H_0: Disagreeing with information in the DSS is not a factor in the occurrence of diagnostic error.

2Dix.H_1: The DSS information being potentially harmful is a factor in the occurrence of diagnostic error.

2Dix.H_0: The DSS information being potentially harmful is not a factor in the occurrence of diagnostic error.

Assumptions and Limitations

This study makes several assumptions. The first is that critical care physicians have access to and are making use of Decision Support Systems (DSS) during the diagnostic process. The second assumption is that physicians will be open and honest in answering survey questions about changing diagnoses and the potential harm of not having changed a diagnosis. The third assumption is that critical care physicians are not working solely in critical care units or only with critically ill patients. This final assumption can be considered a limitation as well.

A limitation of the study is the inability to specifically target physicians working in critical care units for the survey. Therefore, the study targets physicians with a critical care specialty and determines whether the incident being studied involves a critically ill patient. This could lead to a second limitation of only receiving survey results about non-critically ill patients. The final limitation is related to receiving permissions from healthcare organizations for their physicians to participate in the study. This constraint creates a small population size for the survey.

Summary

This chapter includes the background, problem statement, purpose of the study, definitions, significance of the study, research questions, and assumptions and limitations. The background included information on diagnostic error and possible causes. Diagnostic error is starting to be recognized as a real issue as shown by research conducted by the Institute of Medicine in 2000 and 2015. While the 2000 study highlighted problems in patient safety and quality care (Kohn, Corrigan, & Donaldson), the follow-up study in 2015 took the next step in improving quality of care by focusing on improving diagnosis (Balogh, Miller, & Ball). The highest cause for error has been the absence of differential diagnosis (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012, Graber, Franklin, & Gordon, 2005; Schiff et al., 2009).

The problem statement pointed out the lack of known solutions for diagnostic error and the need to evaluate potential solutions such as decision support systems (DSS), which have been identified as a potential solution that addresses the differential diagnosis aspect of diagnostic error (MLA, 2013). The purpose of this study is to evaluate DSS as a potential solution to diagnostic error because much of the existing literature does not evaluate these solutions in a clinical setting. Given that the highest rates of error occur in critical care settings (Jayaprakash et al., 2019; Winters et al., 2012), it is important to study the effects DSS have on diagnosis in critical care settings.

This chapter also discussed the definitions of terms needed for the study such as diagnostic error, DSS, and differential diagnosis. The significance of the study examined the benefits for healthcare, library science, and information science. Next, the two main research questions were discussed: does the use of a decision support system during diagnosis reduce diagnostic error and how are decision support systems used in critical care settings? Finally, the assumptions and limitations were briefly discussed with the main limitation being the potential for a small sample size.

CHAPTER 2

LITERATURE REVIEW

In order to discuss diagnostic error, the diagnostic process must be understood as well as diagnostic error causes. This literature review is limited to the scope of decision support systems (DSS) in relation to diagnosis. In addition, the literature on DSS as a diagnostic error solution will be examined. Decision Support Systems (DSS) are also a route to engage in differential diagnosis to reduce diagnostic error and therefore the research on DSS providing correct differential diagnosis is explored. Finally, the studies that address diagnostic error and DSS use in critical care units are inspected.

The Diagnostic Process

Symptoms can belong to more than one disease (Bosk, 1980), which is why the patient's illness history over time is an important part of the diagnostic process (Baerheim, 2001; Peterson, Holbrook, Von Hales, Smith & Staker, 1992). One study indicated in 76% of cases the diagnosis could be solely based on patient history (Peterson, Holbrook, Von Hales, Smith & Staker, 1992). The diagnostic process is cyclical and usually starts with the doctor developing a hypothesis based on symptoms and patient history and then endeavors to prove or disprove the hypothesis (Berner & Graber, 2008). Beerheim (2001) refers to this as a two-phase approach; abductive and deductive. Abductive is the phase in which the hypothesis is formed, and one or more diagnoses are suggested while the deductive phase is the physician's acceptance or rejection of the diagnosis. Schiff et al. (2005) agree and describes the diagnostic process in a set of seven steps: "(1) access/presentation, (2) history taking/collection, (3) the physical exam, (4) testing, (5) assessment, (6) referral, and (7) follow up" (p. 261).

Croskerry (2009) presents a diagnostic process model which focuses more on decision making than hypothesis generation. Decision making is either part of a System 1 or System 2 process. System 1 is comprised of a pattern of symptoms that allow a physician to make an immediate diagnosis, while System 2 deals with an unrecognized diagnosis in which further testing and research have to be completed before reaching a diagnosis. The System 2 processes are where hypothesis generation occurs.

El-Kareh, Hasan, and Schiff (2013) combined both types of diagnostic models mentioned above. Like Croskerry's (2009) model, if a pattern is recognized the physician skips hypothesis generation, but assesses the treatment plan to verify diagnosis mimicking Beerheim's (2001) Step 4. When a pattern is not recognized the physician engages in differential diagnosis or hypothesis generation. What all of the models have in common, but is not explicitly stated, is engaging in differential diagnosis (DDX) when a pattern is not clearly identified. DDX takes place during the assessment phase (Schiff et al., 2005), but Baerheim (2001) suggests that the actual diagnosis starts during the physical exam and the testing is part of confirming or rejecting the diagnosis. Both Croskerry (2009) and El-Kareh et al. (2013) limit DDX to when a clear pattern of symptoms do not emerge from initial data gathering. This suggests that for the purpose of DDX, a decision support system (DSS) could be best inserted between Schiff et al. (2005) diagnosis Steps 3 and 4 as well as during Step 5. After all, Berner and Graber (2008) pointed out that physicians are only using DSS when they know their diagnosis is incorrect, suggesting that they do not recognize a clear pattern.

When considering diagnostic aids, it is important to remember that the diagnostic process is customized based on the internalization of the individual medical practitioner's knowledge (Newman-Toker & Pronovost, 2009), meaning "…the diagnostic process is difficult to be standardized" (Matsumura et al., 2012, p. 318). It is easy to determine a patient has a certain disease if the medical practitioner has knowledge of the disease (Matsumura et al., 2012), which is in part why "[d]iagnosis is still largely viewed as an individual art rather than evidence-based science" (Newman-Toker & Pronovost, 2009, p 1061). MacDonald (2011) found that diagnosis was equally viewed as a science as well as an art by 74% of physicians. Decision support systems (DSS) help marry this idea of art and science in diagnosis by generating potential diagnoses (Bond et al., 2012) alleviating physicians reliance on either memory or experience. This is why Matsumura et al. (2012) believe the use of a DSS is important during initial diagnosis. This suggests that not only can use of a DSS improve diagnosis but help standardize the diagnostic process by providing a standardized set of knowledge to the medical community.

Diagnostic Error Causes

There are several causes of diagnostic error. The research discusses two types of diagnostic error: system related error and cognitive error. System related errors are those made due to technical failure or organizational flaws (Graber, Franklin, & Gordon, 2005). Cognitive errors are made because of faulty data gathering (not enough patient history), faulty synthesis of data (misinterpreting test results), overconfidence (not engaging in information seeking behaviors) (Graber, Franklin, & Gordon, 2005; Schiff et al., 2005; Berner & Graber, 2008; Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012). Graber, Franklin, and Gorden (2005) found that cognitive error occurred slightly more frequently than system error when gathering data from self-reporting and quality assurance reports. However cognitive error over system error was the cause in 90% of cases when gathering data from autopsy reports (Graber, Franklin, & Gordon, 2005). This research suggests the greatest impact on reducing diagnostic error is to reduce cognitive error. Considering alternate diagnoses is important because the most common cognitive error is not considering the possibility of other diagnoses, which is referred to as differential diagnosis (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012; Graber, Franklin, & Gordon, 2005; Schiff et al, 2009). Despite most errors being cognitive in nature, it does not preclude system related solutions to improve cognitive error such as the implementation of decision support systems (DSS) (Newman-Toker & Pronovost, 2009).

Scope of Decision Support Systems

As early as 1984, Miller and Black were assessing decision support systems (DSS). While the technology has been around for several decades, technology changes quite rapidly, which does not allow for comparing a DSS from 1985 to a DSS of today. Garg et al. (2005) recognized this 15 years ago when talking about decision support systems (DSS): "[t]his field is rapidly evolving because of technological advances, increasing access to computer systems in clinical practice and growing concern about the process and quality of medical care" (p.1224). Despite the rapid change developments in diagnostic health information technology has not changed significantly over the past ten years (El-Kareh, Hasan, & Schiff, 2013). For these reasons, the the DSS literature review will be limited to studies conducted from 2000 to 2019. Trowbridge and Weingarten (2001) report that the majority of studies show positive results for patients with the use of DSS, such as short hospital stays or fewer medication errors. Given that diagnostic error is the focus of this study, research will be limited to studies in which DSS are being used as diagnostic aids. For a complete review of decision support systems used in healthcare prior to 2000 see Hunt, Haynes, Hanna, and Smith (1998). Finally studies were excluded if they included authors who also created a commercial DSS as Garg et al. (2005) found these studies always reported better results than those with unaffiliated authors.

There are different types of decision support systems (DSS), despite having the same name. All types of DSS used within the medical community are being utilized in some form to improve diagnosis (Trowbridge & Weingarten, 2001). There are DSS for interpreting diagnostic imaging tests (Dunne et al., 2015; Ip et al., 2012), while others are used to manage specific diseases such as hypertension or heart disease (DeBusk, Miller, & Raby, 2010; Miller & Black, 1984). There are also many studies that focus on these various DSS as they relate to particular area of medicine such as pediatrics (Bavdekar & Pawar, 2005; Folkens, 2009). The DSS that help with interpreting diagnostic imaging are outside the scope of this study as they in themselves are not offering assistance in generating optional diagnoses. For the purpose of this study the focus will be differential diagnosis as the diagnostic aid, which was the suggested cause of diagnostic error (Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alesandro, 2012).

Decision Support Systems and Diagnostic Error

Twenty-three studies published since 2000 were found that examined both decision support systems (DSS) and diagnosis. Of those twenty-three studies, six were systematic reviews(Belard et al., 2017; El-Kareh, Hasan, & Schiff, 2013; Garg et al., 2005; Medow, Arkes, & Shaffer; Riches et al., 2016; Sim et al., 2001; Trowbridge & Weingarten, 2001), one of which was a meta-analysis of the meta-analysis (Trowbridge & Weingarten, 2001) and another a review of a meta-analysis conducted at a conference (Sim et al., 2001). Nine of the studies used sample cases to test diagnoses with the use of a DSS (Bavdekar & Pawar, 2005; Berner, Maisiak, Heudebert, & Young, 2003; Bond et al., 2012; DeBusk, Miller, & Raby, 2010; Folkens, 2009; Graber & Matthew, 2008; Kostopoulou, Porat, Corrigan, Mamoud, & Dulaney, 2017; Lindgaard, Pyper, Frize, & Walker, 2009; Martinez-Franco et al., 2018) and only five studies were conducted in live settings with clinicians using a DSS to make diagnoses in real time (Arancibia et al., 2019; Graber & VanScoy, 2003; Elkin et al., 2010; Phua, See, Khalizah, Low, & Lim, 2012; Shimizu, Nemoto, & Tokuda, 2018). The final two studies addressed developing DSS (Cahan & Cimino, 2017; Crowley et al., 2013). A table classifying these studies and their conclusions can be found in Appendix A.

Even fewer studies examined the impact of Decision Support Systems (DSS) on the reduction of diagnostic error. Of the seven studies that examined diagnostic error, one focused more on detecting biases and things to consider in the development of a DSS (Crowley et al., 2013), while the other six found that diagnosis could be improved with the use of a DSS (Folkens, 2009; Graber & Matthew, 2008; Kostopoulou, Porat, Corrigan, Mamoud, & Dulaney, 2017; Martinez-Franco et al., 2018; Riches et al., 2016; Shimizu, Nemoto, & Tokuda, 2018). Ultimately, more research is needed both in part to confirm results and because the study of diagnostic computer systems such as DSS for use in healthcare is still developing (El-Kareh, Hasan, & Schiff, 2013).

As the field of research develops on decision support systems (DSS) and diagnosis, it is important to note that several issues are found in the review of related literature. The first issue concerns the systematic review of older studies where findings are based on the use of outdated technology With the exception of Belard et al. (2017), Trowbridget and Weingarten

(2001) and Sim et al. (2001), the systematic reviews examined other studies on DSS and diagnosis that were at least four years old. One such example is the 2005 systematic review of decision support systems (DSS) conducted by Garg et al. Of the 100 studies evaluated, only 10 used a DSS in diagnosis. Sixty percent of these 10 studies were conducted before 2000 (more than 5 years old in 2005) with the oldest published in 1975. When referring to 47% of all the studies examined, Garg et al. (2005) stated it best as "[m]ost of these were early generation systems lacking the full functionality of current systems" (p. 1225). As late as 2016, Riches et al. were still recommending further study to determine the impact on diagnosis. Despite the time difference Riches et al. (2016) only found 36 eligible studies on DSS as compared to Garg et al. (2005) 100 studies. This was in part due to the more narrow focus of diagnosis versus patient outcomes. Seventy-five percent of Riches et al. (2016) studies were older than 10 years. Though, the meta-analysis did find that the newer tools had the highest diagnostic rates and the decision support systems had the same rate of diagnostic accuracy as physicians. However, these findings were based on just five cases, three of which were conducted in the 90's. Despite the positive findings, Riches et al. (2016) pointed out that many of the results had a high heterogeneity rating, meaning it was difficult to find standardization among the studies and making comparisons was suboptimal. According to Riches et al. (2016) these findings point out the need for further research and standardization. Despite this, meta-analysis allowed researchers to find patterns in research that otherwise might not be discovered without more lengthy and expensive studies.

A second issue is that many of the decision support systems (DSS) and diagnostic studies are not conducting field research. Consequently, many of the conclusions indicate that DSS could improve diagnosis, but further research needs to be completed in a clinical setting (Bond et al., 2012; El-Kareh, Hasan, & Schiff, 2013; Garg et al., 2005; Riches et al., 2016; Sim et al., 2001; Singh, Schiff, Graber, Onakpoya, & Thompson, 2017; Trowbridge & Weingarten, 2001). While these types of studies can be very useful, they do not highlight what is actually happening in practice with the use of a DSS, but rather what could happen if a DSS were used as a diagnostic aid. Once again these studies are highlighting the need for further research without offering clinical evidence that diagnosis is effected by the use of a DSS (Bond et al., 2012; Elkin et al., 2010; Folkens, 2009; Graber & Matthew, 2008; Lindgaard, Pyper, Frize, & Walker, 2009). While these studies provide a critical first step in the research of DSS and diagnosis, they also illustrates Henrikson and Brady's (2013) conclusions that there is a gap between ideas to reduce diagnostic error and the implementation/evaluation of ideas to confirm whether or not the change did in fact have an effect.

Only five of the studies were conducted in a clinical setting, bridging the gap between implementation and evaluation. The first was Elkin et al. (2010) which found the DSS, DxPlain, was useful. However, they were only evaluating diagnostically challenging situations. Additionally, the authors did not examine diagnostic error. Instead, they compared healthcare costs for diagnostically challenging cases and found that the use of a DSS could save money. While Elkin et al. (2010) had a control period where no DSS was used and a test period during which a DSS was used, the cases were not the same. Therefore, the comparison of healthcare costs was made between cases that may have been significantly more costly than comparison cases. Ultimately, the findings suggest more research is needed. Arancibia et al. (2019) also was not looking specifically at diagnostic error. This study looked at triage of patients in the emergency department. After a physician triaged patients a researcher used a DSS to interview patients and compare results with a physician. While no statistically significant results were obtained, it was suggested that a DSS could speed up the emergency room process. In the third study, Graber and VanScoy (2003) looked at the use of a DSS in an emergency department. This study compared the exact same patients and diagnoses with and without using a DSS. Their findings indicate that DSS have the same percentage of success in providing the correct diagnosis in emergency departments as previous studies found for other clinical settings. The definition of success for Graber and VanScoy (2003) was whether or not the DSS contained the diagnosis reached by the physician. This was achieved by observing the diagnostic process and then entering data into the DSS after the fact and seeing if the diagnosis appeared in the results. There was no system for determining if the diagnosis was successful or how the physician may have altered the diagnosis based on findings in the DSS. While the fourth clinical study focused on the use of a DSS, it looked at the use in terms of clinicians getting answers to clinical questions and not necessarily as a diagnostic aid. However, it did present some findings that DSS were useful as a diagnostic aid. The study was conducted in a critical care unit and will be discussed in greater detail in the critical care section (Phua, See, Khalizah, Low, & Lim, 2012). Despite the limitations of these studies, they provide evidence that DSS can improve the diagnostic process. Shimizu, Nemoto, and Tokuda (2018) was the final clinical study, conducted in Japan for out-patient care. It was the only study focused on the reduction of diagnostic error. The study looked at two groups of physicians treating patients: one with access to the DSS, UpToDate, and one without access to the DSS. Shimizu, Nemoto, and Tokuda's (2018) reviewed patient charts for the physicians and their findings were statistically significant with

UpToDate physicians experiencing an error rate of 2% and physicians without UpToDate having an error rate of 24%.

Graber and Matthew (2008), Folkens (2009), Riches et al. (2016), Martinez-Franco et al. (2018), Kostopoulou, Porat, Corrigan, Mamoud, and Dulaney (2017), and Shimizou, Nemoto, and Tokuda (2018) all examined diagnostic error and decision support systems (DSS). All six studies point to fewer diagnostic errors with the use of a DSS. Graber and Matthew (2008) evaluated the DSS Isabel by entering test cases in which the diagnosis was known and believed to be correct. They found that Isabel provided the correct diagnosis between 74% and 96% of the time. Folkens (2009) also used sample cases to study the effect of the DSS NeoPeDSS on diagnosis. Participants were asked to make a diagnosis, then they were trained on the use of the DSS and asked to again make a diagnosis. The participants were "…recruited from hospitals with Neonatal Intensive Care Units from Canada and the United States" (Folkens, 2009, p. 25). Findings indicated improved accuracy in diagnosis based on residents changing their diagnosis after using the DSS (Folkens, 2009). Riches et al. (2016) as discussed earlier, used meta-analysis looking at previous literature on DSS as a diagnostic aid. They found that there was potential for DSS to advance the diagnostic process. Martinez-Franco et al. (2018) studied medical residents in their first year instead of physicians. Residents were put into two groups: one with access to the DSS DXplain and one without access to the DSS. Residents participated in a test that required them to evaluate 30 cases. The results were an increase of 8.3% in diagnostic accuracy when using DXplain. Kostopoulou, Porat, Corrigan, Mamoud, and Delaney (2017) found close to the same results with a diagnostic accuracy increase between 8% and 9%. However, this study looked a prototype DSS and used actors as patients. There were two groups of patients, but the same physicians consulted both groups of patients using the DSS with only one group. The final study Shimizu, Nemoto, and Tokuda (2018) as discussed earlier had a clear correlation between the use of the DSS UpToDate and reduction in diagnostic error.

Decision Support Systems (DSS) as a Diagnostic Error Solution

There have been several suggestions on reducing diagnostic errors. Newman-Toker and Pronovost (2009) suggest developing new methods in diagnostic education. While this is a worthwhile strategy, diagnostic error would not be reduced until the next generation of doctors. How can diagnostic errors be reduced in already practicing physicians? Berner and Graber (2008) suggest making data more accurate and accessible. Checklists are one suggestion for making the diagnostic process more accurate (Ely, Graber, & Croskerry, 2011). A checklist can prompt a physician to research other diagnoses, but it does not provide alternate suggestions. Carr (2014) suggests improving the electronic medical record. This is another great strategy, but the medical record itself just provides data and does not address differential diagnosis. However, there are decision support systems that can be integrated into the medical health record to suggest possible diagnoses (Bond et al., 2012). These same systems can be used as standalone products as well. The key to reducing diagnostic error may be in the use of decision support systems for differential diagnosis. During the MLA (2013) webinar on diagnostic error Dr. Mark L. Graber indicated that decision support systems could help in reducing the rate of diagnostic error. Dr. Graber also stated that he personally used a decision support system, Isabel, during his diagnostic process. If the problem is that cognitive diagnostic error is occurring due to failure to consider alternate diagnoses and decision support systems suggest alternate diagnosis, then perhaps a solution is to use a DSS.

Decision Support Systems and Differential Diagnosis

Despite findings indicating improved diagnostics, decision support systems (DSS) have not become prevalent in clinical use (Graber & Mathew, 2008). Garg et al. (2005) found that DSS contained the correct diagnosis in 64% of cases. Graber and Mathew (2008) reported that Isabel, a popular DSS, contained the correct diagnosis 96% of the time, with the diagnosis being listed on the first result page 51% of the time. Graber and Mathew (2008) further broke down results based on manual entry into the DSS versus copy and paste data entry methods. The rate of correct diagnosis for Isabel dropped to 76% when using the copy and paste method. In 2012 Bond et al. found that Isabel only had a success rate of 45% while another DSS, DXplain, was successful 50% of the time. Another popular DSS, UpToDate, was found have a success rate of 98% (2012). Additionally, it was found the DSS reduce the admittance rate by up to 15% (Garg et al., 2005). Isaac, Zheng, and Jha (2012) found that UpToDate also reduced the length of hospital stays. While the last two studies do not directly address diagnosis, they show positive patient outcomes when a DSS is used. Additionally, all of these studies show the potential usefulness in using DSS for considering optional diagnoses, better known as differential diagnosis.

Finally despite the availability of decision support systems (DSS) such as UpToDate (Bradley, Getrich, & Hannigan, 2015) and the research that indicates they can be used to improve diagnosis (Berner & Graber, 2008; DeBusk, Miller, & Raby, 2010; Folkens, 2009; Garg et al., 2005; Riches et al., 2016; Shimizu, Nemoto, & Tokuda, 2018), many physicians simply are not using them (Berner & Graber, 2008; Singh, Schiff, Graber, Onakpoya, & Thompson, 2017). Physicians are only using the DSS when they know their initial diagnosis is wrong (Berner &

Graber, 2008). Berner, Masiak, Heudebert, and Young (2003) found that even when using the DSS, clinicians tend to stick with their original diagnosis if it appears in the first ten results. Lindgard, Pyper, Frize, and Walker (2009) also found that clinicians tend to pay more attention to first results in a list of possible diagnoses. This overconfidence of physicians combined with DSS only being used by choice suggest cognitive diagnostic errors will continue despite a DSS ability to provide additional expertise (Berner & Graber, 2008). While Berner's and Graber's (2008) findings indicate that requiring the use of DSS would lower cognitive error, the findings of Berner, Masiak, Heudebert, and Young (2003) suggest physicians would still fall prey to decision bias. However, this does not mean diagnosis would not be improved; but rather, diagnostic error would not be completely eliminated with the use of a DSS. Given these outcomes, it is important to design a study that examines the relationship between DSS and diagnostic error within a live clinical setting in which the same case can be evaluated with and without the use of a DSS. Additionally, since DSS cannot hope to completely eradicate diagnostic error, the study should focus on areas in which diagnostic error is highest.

Critical Care Units

It has been estimated that anywhere from 34,000 to 40,500 patients in critical care will die annually due to diagnostic error (Winters et al., 2012; Wong, Osborne, & Waldmann, 2015). Tejerina et al. (2012) found that diagnostic error was occurring at a rate of 18.5% of the time in critical care units while Shojania, Burton, McDonald, and Goldman (2003) found the rate could be as high as 24.4%. However, Winters et al. (2012) found the rate to be closer to 28%. The most recent study found a diagnostic error rate of 17.7% for cirtically ill patients (Jayakaprash et al., 2019). Patients in critical care units are at least 16% more likely to experience a diagnostic error than those in other areas of the hospital and in some cases 48% more likely to experience a diagnostic error (Winters et al., 2012). These statistics provide a clear need for ways to reduce diagnostic error in critical care units. Unfortunately, there are even fewer studies looking at the use of decision support systems (DSS) as a diagnostic aid in critical care than there are in general care. Williams, Bratton, and Hirshberg (2013) admit that there is a gap in the research in this area despite the potential for DSS to deliver a faster diagnosis.

One of the few studies found looking at DSS in critical care units did not focus specifically on diagnosis. The study addressed seeking information to clinical questions. Additionally, the study did not focus exclusively on critical care physicians. While the study did find that diagnoses were changed due to the use of the DSS less than 10% of the time, the study did not distinguish between the results of the critical care unit and the general hospital (Phua, See, Khalizah, Low, & Lim, 2012). Another study focused on the use of the DSS Isabel in the pediatric critical care unit and found that Isabel contained the correct diagnosis more than 80% of the time for the most common diseases, but overall only had a 4.21% accuracy rate (Bavdekar & Pawar, 2005). There were two studies that did focus on both critical care units and DSS as diagnostic aids. The first study was conducted by Folkens (2009) who found that DSS improved diagnosis. The specifics of the study were discussed early in this paper. However, the second study did not focus on whether or not there was a diagnostic error, but whether or not residents would change their decisions to admit patients to ICU based on contradictory diagnostic evidence from a DSS or an anonymous specialist. The research showed that residents were more likely to change their decisions based on information provided by a DSS

(Medow, Arkes, & Shaffer, 2010). Despite the scarcity of research in this area, these studies indicate both a need for further study and the potential for DSS to have an impact on diagnosis.

Summary

This chapter discussed the literature which included the diagnostic process, diagnostic error causes, scope of decision support systems (DSS), DSS and diagnostic error, DSS as a diagnostic error solution, DSS and differential diagnosis, and critical care units. In the literature there is a lack of studies conducted that evaluate solutions for the reduction of diagnostic error in clinical settings. Furthermore, while the research points toward decision support systems (DSS) as a possible aid in the reduction of diagnostic error, the DSS are not being used consistently. Finally, there is a lack of studies in this area targeting critical care units.

CHAPTER 3

METHODS

This study is viewed from the postpositive worldview in which "…causes (probably) determine effects or outcomes" (Creswell, 2014, p. 7). This research explores the use of decision support systems as a cause of reduction in diagnostic error by critical care physicians. Even though some studies have looked at diagnostic error in a clinical setting, they have not been able to use the same patient and diagnostic case for comparison in a diagnostic error versus a correct diagnosis. Because the diagnostic process can be different with each patient and disease, it is important to be able to compare the use and non-use of decision support systems (DSS) in the exact same situations and patients.

A convergent parallel mixed methods design was used, which means that both quantitative and qualitative data were collected at the same time (Creswell, 2014). A survey was chosen as the research instrument due to the existence of the information assessment method (IAM), which has been documented as a valid instrument for assessing the benefits of information retrieved from electronic resources such as a DSS (Information Technology Primary Care Research Group, 2017; Pluye et al., 2013). The IAM questions are discussed in greater detail later in this chapter and are also listed in Appendix B. The survey utilized both open ended and close ended questions to collect data. This allowed physicians to reflect on a case in which they used a DSS and compare the outcome to what might have happened without the use of a DSS. This study achieved the goal of comparing the use and non-use of decision support systems (DSS) in the exact same situations and patients by asking physicians to answer questions about cases in which they used a DSS to make a diagnosis and then compare what might have happened had the DSS not been used (nothing, new diagnosis, or confirm diagnosis). Because diagnostic error can be a sensitive topic and physicians have "…a real concern that diagnostic errors can lead to career-threatening malpractice suits" (Graber, 2005, p. 107), the survey was conducted anonymously.

The data was analyzed under the assumption that a new diagnosis made with a DSS indicates that the original diagnosis (made without a DSS) would have been a diagnostic error. This assumption operationalizes diagnostic error, making it possible to calculate a diagnostic error rate (number of changed DSS assisted diagnosis/number of all DSS assisted diagnosis = diagnostic error rate).

Given the research involved humans, institutional review board (IRB) approval was required. The University of North Texas IRB approved the research design and survey on April 13, 2018. The University of Oklahoma Health Sciences Center (OUSHC) IRB approval was also required because physicians from OUHSC were being surveyed. The OUHSC IRB approved the research design and survey on March 1, 2019.

Data Sample

It can be difficult to obtain a list of physicians and their contact information depending on where they work. Additionally, critical care units often have attending physicians, meaning they do not necessarily work in the critical care unit exclusively. However, The Oklahoma State Medical Board website lists all licensed physicians and their specialties. Those with critical care specialties were targeted for the survey. Most states in the US have a similar website, but not all of them offer the information in a way that can be used to conduct a survey. Therefore, the sample of physicians used in this study was limited to Oklahoma physicians with a critical care specialty and who were listed as active on the Oklahoma State Medical Board website. A script (Appendix D) was used to query the website and identify all of the relevant physicians, totaling 299. Due to the difficulty in obtaining permissions for physicians to participate in the survey from all the healthcare systems across the state of Oklahoma, the sample needed to be narrowed. Nonprobability sampling is suggested when experts such as physicians are required, and therefore, a purposive sample was taken from the sampling frame (Bernard, 2006) by targeting the physicians from the Oklahoma University Medical Center. This group was chosen because the attached medical library is known to provide access to a decision support system and because the researcher has knowledge of the associated institutional research board.

Table 1

Physician Specialty Breakdown

Critical Care Specialty	Number of OU Medical Physicians
Anesthesiology	3 (9%)
Internal Medicine	6 (19%)
Pediatrics	9 (28%)
Pulmonary	7 (22%)
Surgical	7 (22%)
Total	32

The Oklahoma University (OU) Medical Center has 707 beds and is a nonprofit hospital (American Hospital Directory, 2017c). The OU Medical Center is also affiliated with the University of Oklahoma (OU) College of Medicine where many of the professors are also clinicians (Board of Regents of the University of Oklahoma, 2016). The Medical Board population size totaled 45 physicians. However, only 32 of these physicians were listed as being active by OU. Table 1 gives a breakdown of the population with the number of physicians in each critical care specialty.

Each physician received a postcard (Figure 1) in the mail advertising the survey. A mailed survey is likely to have a minimal response rate of only 20% (Bernard, 2006) thus reducing my sample size to 8 respondents. The Dillman method, such as using light green paper for mailings and a focus on interest inducing titles, can increase response rates to as much as 70% (Bernard, 2006). Additionally, the survey was emailed in hopes of increasing the response rate. Dr. Brandt Wiskur, Director of Institutional Research at the University of Oklahoma Health Sciences Center (OUHSC), was able to obtain physician email addresses with the approval of the OUHSC Institutional Review Board and sent the initial email survey. A final strategy for encouraging responses was to offer a chance to win one of two $50 Amazon gift cards.

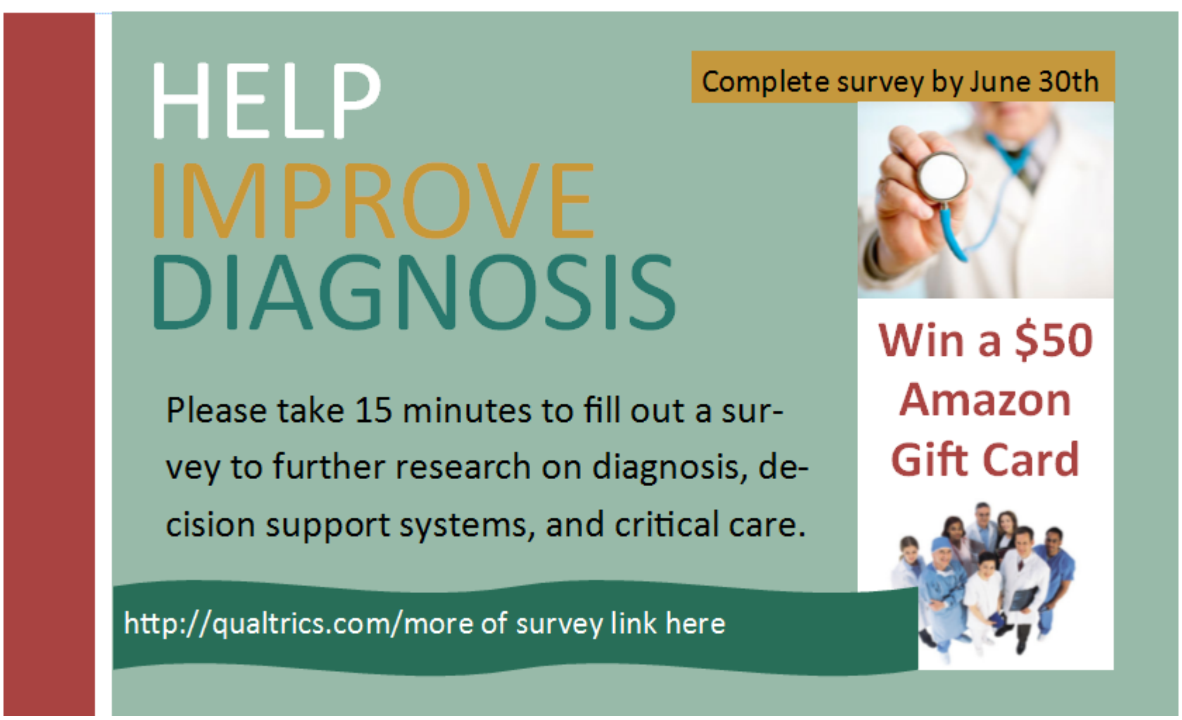

Figure 1. Image of postcard sent to physicians to advertise survey.

In addition to selecting the physicians in this study using a purposive sampling method, the physicians self-selected into two groups: those using decision support systems (DSS) and those not using a DSS. According to Bernard (2006), this is a concern because if it is found that using a DSS improves diagnosis, the researcher cannot be certain that it is not because the types of physicians who choose to use a DSS as a diagnostic tool are more likely to consider alternate diagnoses. Therefore, they might have a lower diagnostic error rate even without the DSS. However, the survey addresses this issue by asking the physician a question about whether they are required to use a DSS.

Data Collection

The beginning of the survey requests basic demographic information such as the physician's specialty and length of practice. There are also questions asking why a decision support system (DSS) was used, whether or not it was used in conjunction with a diagnosis, and if the diagnosis was for a critically ill patient. There are additional questions addressing the impact of using a DSS on the physician's practice and which DSS was used. The full survey is listed in Appendix C. This survey data will speak directly to the following research questions and hypotheses:

1. Does the use of a decision support system during diagnosis reduce diagnostic error?
    - B. How does critical care physician attributes (medical credentials, type of specialty, and time practicing medicine) impact diagnostic error?
        - 1Bi.H_1: The type of medical credentials is a factor in the occurrence of diagnostic error.
        - 1Bi.H_0: The type of medical credentials is not a factor in the occurrence of diagnostic error.
        - 1Bii.H_1: Having an internal critical care specialty is a factor in the occurrence of diagnostic error.

1Bii.H_0: Having an internal critical care specialty is not a factor in the occurrence of diagnostic error.

1Biii.H_1: Having a pediatrics critical care specialty is a factor in the occurrence of diagnostic error.

1Biii.H_0: Having a pediatrics critical care specialty is not a factor in the occurrence of diagnostic error.

1Biv.H_1: Having a pulmonary critical care specialty is a factor in the occurrence of diagnostic error.

1Biv.H_0: Having a pulmonary critical care specialty is not a factor in the occurrence of diagnostic error.

1Bv.H_1: Having a surgical critical care specialty is a factor in the occurrence of diagnostic error.

1Bv.H_0: Having a surgical critical care specialty is not a factor in the occurrence of diagnostic error.

1Bvi.H_1: Having an anesthesiology critical care specialty is a factor in the occurrence of diagnostic error.

1Bvi.H_0: Having an anesthesiology critical care specialty is not a factor in the occurrence of diagnostic error.

1Bvii.H_1: The amount of time a physician has practiced medicine is a factor in the occurrence of diagnostic error.

1Bvii.H_0: The amount of time a physician has practiced medicine is not a factor in the occurrence of diagnostic error.

2. How are decision support systems used by critical care physicians?

   A. For what purposes are critical care physicians using a DSS?

      2Ai.H_1: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is a factor in the occurrence of diagnostic error.

      2Ai.H_0: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is not a factor in the occurrence of diagnostic error.

      2Aii.H_1: Critical care physician use of a DSS to fulfill a personal educational objective is a factor in the occurrence of diagnostic error.

      2Aii.H_0: Critical care physician use of a DSS to fulfill a personal educational objective is not a factor in the occurrence of diagnostic error.

      2Aiii.H_1: Critical care physician use of a DSS to satisfy curiosity or for personal interest is a factor in the occurrence of diagnostic error.

2Aiii.H_0: Critical care physician use of a DSS to satisfy curiosity or for personal interest is not a factor in the occurrence of diagnostic error.

2Aiv.H_1: Critical care physician use of a DSS to look up something forgotten is a factor in the occurrence of diagnostic error.

2Aiv.H_0: Critical care physician use of a DSS to look up something forgotten is not a factor in the occurrence of diagnostic error.

2Av.H_1: Critical care physician use of a DSS to share information with a patient, their family, or home health aides is a factor in the occurrence of diagnostic error.

2Av.H_0: Critical care physician use of a DSS to share information with a patient, their family, or home health aides is not a factor in the occurrence of diagnostic error.

2Avi.H_1: Critical care physician use of a DSS to exchange information with other health professionals is a factor in the occurrence of diagnostic error.

2Avi.H_0: Critical care physician use of a DSS to exchange information with other health professionals is not a factor in the occurrence of diagnostic error.

B. How often are critical care physicians using a DSS?

2Bi.H_1: The frequency of critical care physicians use of a DSS is a factor in the occurrence of diagnostic error.

2Bi.H_0: The frequency of critical care physicians use of a DSS is not a factor in the occurrence of diagnostic error.

C. What type of patients do critical care physicians use DSS to diagnose; critically ill or non-critically ill patients?

2Ci.H_1: The use of DSS by critical care physicians with critically ill patients is a factor in the occurrence of diagnostic error.

2Ci.H_0: The use of DSS by critical care physicians with critically ill patients is not a factor in the occurrence of diagnostic error.

2Cii.H_1: The use of DSS by critical care physicians with non-critically ill patients is a factor in the occurrence of diagnostic error.

2Cii.H_0: The use of DSS by critical care physicians with non-critically ill patients is not a factor in the occurrence of diagnostic error.

Q1. Why did you do this search for information? ***Check all that apply***

- ☐ To address a clinical question (problem) about a specific patient
- ☐ To fulfil a personal educational objective
- ☐ To satisfy curiosity or for personal interest
- ☐ To look up something I had forgotten
- ☐ To share information with a patient, their family, or home health aides
- ☐ To exchange information with other health professionals (e.g., a colleague)
- ☐ To manage aspects of patient care with other health professionals

Q2. Did you find relevant information that partially or completely met your objective(s)?

☐ Yes ☐ No

Q3. What is the impact of this information on you or your practice? ***Check all that apply***

- ☐ My practice was (will be) changed and improved
- ☐ I learned something new
- ☐ This information confirmed I did (am doing) the right thing
- ☐ I am reassured
- ☐ I am reminded of something I already knew
- ☐ I am dissatisfied
- ☐ There is a problem with the presentation of this information
- ☐ I disagree with the content of this information
- ☐ This information is potentially harmful

Q4. Did you (will you) use this information for a specific patient?

☐ Yes ☐ No ☐ Possibly ***If YES: Check all that apply***

- ☐ As a result of this information I managed (or will manage) this patient differently
- ☐ I had several options for this patient, and I used (will use) this information to justify a choice
- ☐ I did not know what to do, and I used (will use) this information to manage this patient
- ☐ I thought I knew what to do, and I used this information to be more certain about the management of this patient
- ☐ I used this information to better understand a particular issue related to this patient
- ☐ I used (will use) this information in a discussion with this patient, or with other health professionals about this patient
- ☐ I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change for this patient

Q5. For this patient, did you observe (or do you expect) any health benefits as a result of applying this information?

☐ Yes ☐ No ☐ Possibly ***If YES: Check all that apply***

- ☐ This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors)
- ☐ This information helped to prevent (will help to prevent) a disease or worsening of disease for this patient
- ☐ This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient
- ☐ This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention
- ☐ This information helped to increase this patient's knowledge, or their family or home health aides' knowledge

Figure 2. Information assessment method (IAM; Pluye et al., 2013).

The main body of the survey is comprised of quantitative questions developed using the information assessment method (IAM). See Figure 2 for a list of the five original IAM questions. In order to operationalize diagnostic error, the fourth IAM questions had to be modified to focus on the diagnosis and to categorize the responses into statements that would indicate a diagnostic error would have occurred without the use of a DSS and statements that would not indicate a diagnostic error. For example, Answer 4c would indicate that the physician did not have a diagnosis before using the decision support system and therefore a diagnostic error would have occurred. However, Answer 4 d indicates no diagnostic error as the physician only used the DSS to confirm a current diagnosis. The questions that help determine diagnostic error, the changes to those questions, and their areas of assessment appear in Appendix B. The full survey can be found in Appendix C. This data will answer the following research questions and hypotheses:

1. Does the use of a decision support system during diagnosis reduce diagnostic error?
   A. What effect does the use of decision support systems during the diagnostic process by critical care physicians have on diagnostic error?

      1Ai.H_1: The use of a decision support system by critical care physicians for diagnostic purposes is a factor in occurrence of diagnostic error.

      1Ai.H_0: The use of a decision support system by critical care physicians for diagnostic purposes is not a factor in occurrence of diagnostic error.

   C. Is the relevance of information provided by the DSS a factor in the occurrence of diagnostic error?

      1Ci.H_1: The relevance of information provided by the DSS is a factor in the occurrence of diagnostic error.

      1Ci.H_0: The relevance of information provided by the DSS is not a factor in the occurrence of diagnostic error.

2. How are decision support systems used by critical care physicians?
   D. The outcome of DSS information obtained by critical care physicians may change their practice. How do these changes impact diagnostic error?

      2Di.H_1: Physicians practice changed or improved from use of DSS information is a factor in the occurrence of diagnostic error.

      2Di.H_0: Physicians practice changed or improved from use of DSS information is not a factor in the occurrence of diagnostic error.

      2Dii.H_1: Learning something new from the DSS information is a factor in the occurrence of diagnostic error.

      2Dii.H_0: Learning something new from the DSS information is not a factor in the occurrence of diagnostic error.

2Diii.H_1: Confirming correct actions with the DSS information is a factor in the occurrence of diagnostic error.

2Diii.H_0: Confirming correct actions with the DSS information is not a factor in the occurrence of diagnostic error.

2Div.H_1: Being reassured by the DSS information is a factor in the occurrence of diagnostic error.

2Div.H_0: Being reassured by the DSS information is not a factor in the occurrence of diagnostic error.

2Dv.H_1: Being reminded of something already known by the DSS information is a factor in the occurrence of diagnostic error.

2Dv.H_0: Being reminded of something already known by the DSS information is not a factor in the occurrence of diagnostic error.

2Dvi.H_1: Being dissatisfied with the DSS information is a factor in the occurrence of diagnostic error.

2Dvi.H_0: Being dissatisfied with the DSS information is not a factor in the occurrence of diagnostic error.

2Dvii.H_1: Having an issue with the way information is presented in the DSS is a factor in the occurrence of diagnostic error.

2Dvii.H_0: Having an issue with the way information is presented in the DSS is not a factor in the occurrence of diagnostic error.

2Dviii.H_1: Disagreeing with information in the DSS is a factor in the occurrence of diagnostic error.

2Dviii.H_0: Disagreeing with information in the DSS is not a factor in the occurrence of diagnostic error.

2Dix.H_1: The DSS information being potentially harmful is a factor in the occurrence of diagnostic error.

2Dix.H_0: The DSS information being potentially harmful is not a factor in the occurrence of diagnostic error.

Additional qualitative follow up questions were added to allow confirmation of diagnostic error. The physicians were asked if there was a follow-up with the patient after diagnosis and whether or not the diagnosis could be confirmed as correct with space for the physician to explain how they determined that the diagnosis was correct. Qualitative questions were also used to ascertain what potential harm to the patient would have been caused had the DSS not been used. The last question for all of the physicians was an open-ended question asking for their views of DSS and reduction of misdiagnoses. Finally, all physicians that have not used a DSS were asked to offer their reason(s) for non-use. Table 2 matches the survey questions with the corresponding research questions they help to answer.

Table 2

Matching Survey Questions to Research Questions

Survey Question	Question Topic	Research Question	Purpose
1	Time in Medicine	1B	Determines if time practicing medicine effects DSS use
2	Medical Credentials	1B	Confirms Surveyee is physician
3	Critical Care Specialty	1B	Confirms Surveyee is physician
4	Hospital System	n/a	Confirms Surveyee is physician
5	Frequency of DSS Use	2B	Determines how often DSS are used
6	Why never use DSS	n/a	Guide Future Research
7	Specific DSS used	n/a	Guide Future Research
8	Required to use DSS	n/a	Guide Future Research
9	DSS part of diagnostic process/strategy	1A	Determines is DSS was used as diagnostic aid
10	DSS for critically ill patient	2C	Determines the type of patient treated
11 IAM #1	Why searched DSS for information	2A	Determines the reason for using a DSS
12 IAM #2	Did DSS yield relevant information	1C	Determines if DSS information is appropriate
13 IAM #3	Impact of DSS information on practice	2D	Determines is DSS information changed physician practice
14 IAM #4 Not part of diagnosis	Results if used DSS for specific patient	1A	Determine diagnostic error
15 IAM #5 Not part of diagnosis	Observed patient health benefits from DSS use	1A	Determine diagnostic error
16 IAM #4 part of diagnosis	Results if used DSS for specific patient	1A	Determine diagnostic error

(table continues)

Survey Question	Question Topic	Research Question	Purpose
17 IAM #5 part of diagnosis	Observed patient health benefits from DSS use	1A	Determine diagnostic error
18	Patient diagnosis follow-up and determination of correct diagnosis	1A	Determine diagnostic error
19	Harm if diagnosis was not changed	1A	Determine diagnostic error
20	Opinion on use of DSS and diagnostic error	n/a	Comparison of beliefs versus actions in diagnostic error

Note. IAM questions are listed in the survey twice, but the physicians only see them once according to whether or not they used Decision Support System as part of diagnosis or not.

Table 3

Survey Paths

Path A	Path B	Path C	Path D	Path E
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	7	7	7	7
20	8	8	8	8
	9	9	9	9
	10	10	10	10
	11	11	11	11
	12	12	12	12
	13	13	13	13
	Path C-D	14	16	16
		15	17	17
		20	18	19
			20	20

Note. The numbers represent survey question numbers.

The survey was conducted online using Qualtrics. Qualtrics allows for survey questions to be presented based on the answers to previous questions. For example, in this survey, different questions were presented based on whether or not physicians indicate they have ever used a decision support system (DSS). Appendix C lists the full survey and labels question paths as either A-E. For example, path A is for physicians who have never used a DSS, while path B is for those who have used a DSS. Path B continues to split off questions for those who have used a DSS, but not as part of diagnosis (Path C). Path D is for those that do use a DSS in the diagnostic process and E is for those that changed their diagnosis due to the use of a DSS. Table 3 indicates the survey questions to be answered based on path.

Data Analysis

The data analysis was conducted in three parts. Part 1 is the statistical research design in which the type of data expected to result from collection is analyzed to determine what independent and dependent variables exist, their type, and what statistical tests are appropriate for analysis. Given the statistical tests decided upon, Part 2 codes and cleans the data appropriate to the chosen tests. Part 3 describes the process of running the statistical tests on the coded and cleaned data.

Statistical Research Design

Considering the research questions, there was only one dependent categorical variable, which is the existence of a diagnostic error. However there were multiple categorical independent variables: use of DSS, purpose of use of DSS, DSS information is relevant, frequency of DSS use, type of patient diagnosed using DSS, physicians medical credentials, existence of critical care specialty, required use of DSS, DSS used, and DSS use impact on practice. There is one interval independent variable and that is the length of time the physician has practiced medicine. These variables, their possible categorical values, and the statistics used to analyze the data appear in Tables 4 and 5. The categorical variables fit with chi-square test for independence. Additionally, the chi-square test does not assume a normal distribution and therefore, is a good fit for purposive samples. The chi-square is a good fit if the sample size is small or there are a limited number of cases in each category (Pallant, 2010). Finally, in a personal communication on August 8, 2019 Dr. Jody Worley, a University of Oklahoma professor of research in human relations and a PhD holder in educational psychology research and evaluation, indicated the accepted standard for smaller samples was to use the chi-square test for independence.

Table 4

Linking Research Questions and Variables to Statistical Tests

Research Question	Independent Variable (IV)	Dependent Variable	Statistics
1A	Use of DSS (2 categories)	Existence of Diagnostic Error	Chi Square Test for Independence
1B	Medical Credentials and DSS Use (5 or greater Categories)		
1B	Time in Medicine and DSS Use (Interval)		
1B	Existence of Critical Care Specialty and DSS Use (2 categories)		
1C	DSS Information of Relevance (2 Categories)		
2A	Purpose of DSS Use (6 Categories)		
2B	Frequency of DSS Use (4 Categories)		
2C	Type of Patient for DSS Use(2 Categories)		
2D	DSS Use impact on Practice (9 categories)		

Table 5

Values of Categorical Variables

Q1 Use of DSS	Q2 Purpose of DSS Use	Q2 DSS Information of Relevance	Q3 Frequency of DSS Use	Q4 Type of Patient for DSS Use	Q5 Medical Credentials and DSS Use	Q5 Existence of Critical Care Specialty and DSS Use	Q6 DSS Use Impact on Practice
• Yes • No	• To address a clinical question • To fulfill a personal educational objective • To Satisfy curiosity • To look up something forgotten • To Share info with patient/family/home health • To exchange info with health professionals	• Yes • No	• Daily • Weekly • Monthly • Yearly	• Critically Ill • Non-Critically Ill	• MD • DO • PA • Resident • Nurse • Other	• Yes • No	• Practice changed/ improved • Learned something new • Confirmed correct actions • Reassured • Reminded of something I knew • Dissatisfied • Issue with presentation of info • Disagreed with info • Info potentially harmful

Note. Q1, Q2, Q3, etc. in the headings refer to survey question numbers.

Data Coding and Cleanup

In preparation for statistical analysis using SPSS, the data needed to be coded into categories using numbers. For example, the yes/no for existence of diagnostic error was coded as 0 for No and 1 for Yes. All the categorical variables were coded into ordinal variables to work with chi-square test for independence. The frequency of DSS use was changed for 0 to be equal to never used a DSS, 1 for annual use, 2 for monthly use, etc. For questions that allowed multiple answers, each answer was coded as a separate variable with 0 for no or non-selection and 1 for yes or selection. A copy of the code book can be found in Appendix E. All missing data was coded as 9. In some instances, assumptions were made that turned missing data into an answer of no. Questions 11 and 13 were all based on having used a DSS. It was assumed there was no effect for the five physicians that did not answer the questions because they did not use a DSS and zeroes were recorded. The following assumptions were made, and the data was recoded:

- Question 11 concerned the physician's purpose for using the DSS. It was assumed that since the physicians did not use a DSS they did not have a purpose for using one.
- Question 13 asked about the impact the DSS had on the physician's practice. It was assumed that since the physicians did not use a DSS that a DSS did not impact their practice.

A final assumption was made about Question 20, which asked physicians if they believed the use of a DSS would reduce diagnostic error. Two physicians did not answer the question. Both physicians had used a DSS for diagnostic purposes and therefore it was assumed their answer would have been no, raising our n value from 7 to 9.

Table 6

Hypotheses Excluded due to Insufficient Data

Number	Hypothesis
1Bi.H	The type of medical credentials is a factor in the occurrence of diagnostic error.
1Biv.H	Having a pulmonary critical care specialty is a factor in the occurrence of diagnostic error.
1Bvi.H	Having an anesthesiology critical care specialty is a factor in the occurrence of diagnostic error.
1Ci.H	The relevance of information provided by the DSS is a factor in the occurrence of diagnostic error.
2Aiii.H	Critical care physician use of a DSS to satisfy curiosity or for personal interest is a factor in the occurrence of diagnostic error.
2Aiv.H	Critical care physician use of a DSS to look up something forgotten is a factor in the occurrence of diagnostic error.
2Av.H	Critical care physician use of a DSS to share information with a patient, their family, or home health aides is a factor in the occurrence of diagnostic error.
2Avi.H	Critical care physician use of a DSS to exchange information with other health professionals is a factor in the occurrence of diagnostic error.
2Ci.H	The use of DSS by critical care physicians with critically ill patients is a factor in the occurrence of diagnostic error.
2Cii.H	The use of DSS by critical care physicians with non-critically ill patients is a factor in the occurrence of diagnostic error.
2Dvi.H	Being dissatisfied with the DSS information is a factor in the occurrence of diagnostic error.
2Dvii.H	Having an issue with the way information is presented in the DSS is a factor in the occurrence of diagnostic error.
2Dviii.H	Disagreeing with information in the DSS is a factor in the occurrence of diagnostic error.
2Dix.H	The DSS information being potentially harmful is a factor in the occurrence of diagnostic error.

Once the data was coded, it was clear that some variables would be excluded from the analysis. Physicians chose two of the options concerning the purpose of the DSS search. Therefore, no data existed to answer Research Question 2A hypotheses iii – vi. Because all respondents had the same medical credentials, Question 1B, hypothesis i was excluded. Additional Question 1B, hypothesis iv and vi were excluded because only one physician had a pulmonary critical care specialty and they did not use a DSS and no physicians had an anesthesiology critical care specialty. Several of the answers concerning the impact of the DSS search were not utilized. Consequently, no data existed to answer Research Question 2D, hypotheses vi-ix. All physicians treated critical care patients, and all found the DSS information relevant; so, all hypothesis for Questions 2C and 1C were excluded. The excluded hypotheses are listed in Table 6

Statistical Tests

A chi-squared test was performed in SPSS for each null hypothesis that was stated in chapter 1, which supposes no association between the two variables. The dependent variable for all tests was the operationalization of diagnostic error ($n = 5$) listed in Table 8. After viewing the data, the tests were run a second time with the dependent variable of the physician's opinion on whether or not the use of a DSS would reduce diagnostic error ($n = 7$). For a chi-squared test, the lowest cell frequency should be five or greater and when this assumption is violated for a 2x2 table, Fisher's exact probability test score should be used (Pallant, 2010). SPSS provides Fisher's exact probability test score when running chi-square test as well as the phi (r) correlation coefficient that indicates effect size. It is particularly important to consider effect size with small samples (Kramer & Rosenthal, 1999). Additionally, Dr. Jody Worley (personal communication, August 8, 2019) indicated that a non-significant value of chi-squared with a small samples size was most likely due to having low statistical power. Dr. Worley recommended using the counternull to evaluate effect size. A *p*-value less than .05 (95% confidence interval) failed to reject the null hypothesis and accepts there is no relationship between the two variables (Pallant, 2010), which assumes an effect size of zero (Kramer &

Rosenthal, 1999; Rosenthal, Rosnow, & Rubin, 2000). The counternull is associated with the alternate (or original) hypothesis and has the same *p*-value while "...provid[ing] an effect size value that is equally as likely to be true as the null effect size of .00" (Kramer & Rosenthal, 1999, p. 66). Indicating that if a *p*-value indicates an inability to reject the null hypothesis, then that same *p*-value can be used with the counternull to fail to reject the alternate hypothesis as well. Kramer and Rosenthal (1999) provide the following instructions for calculating the counternull with data that may not be normally distributed:

1. Covert the correlation coefficient (r) to Fishers Zr.
2. Multiply Fishers Zr by 2.
3. Convert the doubled Fishers Zr back to r, which will be the counternull value.

A purposive sample (not normally distributed) was taken for this study, making it a good candidate to evaluate the counternull. The counternull was calculated for each chi-squared/Fishers exact probability value by using the r to z transformation table from Fisher's 1928 text. The resulting counternull effect size was interpreted using Cohen's scale of small, medium, and large (0.10, 0.30, & 0.50) effect sizes (Pallant, 2010).

Summary

This chapter discussed the research methodology. The chapter started with the data sample including the manner in which the population size of 32 critical care physicians was obtained. The data collection which included the development of the survey to be distributed to critical care physicians, was also discussed. Finally, the data analysis was presented in three parts comprising statistical research design, data coding and cleanup, and statistical tests. The dependent and independent variables were defined and their potential values were listed in the statistical research design section. The plans to use the chi-square test for independence were also communicated in the statistical research section. The data coding and cleanup was discussed in the following section. Lastly, the statistical tests section discussed the process of running the tests on the obtained data. All of these areas take into account the expected small sample size due to the difficulty of conducting a survey with physicians concerning a sensitive topic such as diagnostic error.

CHAPTER 4

RESULTS OF THE STUDY

Survey Results

This study examined the use of decision support systems (DSS) in a critical care clinical settings and their effects on diagnostic error. Surveys were disseminated to thirty-two critical care physicians at the University of Oklahoma Medical Center via email with one being returned as undeliverable. This produced a total population of thirty-one. The survey received thirteen responses. Two physicians consented to the survey but did not answer any questions. Two other physicians filled out the survey twice and their second responses were excluded, leaving a sample size of nine. The redundancies were discovered based on emails and date stamps for providing names for the Amazon gift card drawing. One physician filled out for the Amazon card twice and the survey was excluded based on date stamps. The second physician responded to an email in August indicating they had filled out the survey, but their name was included in the Amazon gift card in May. Looking at those dated survey responses and comparing the two, it was reasonably clear it was the same physician.

All nine physicians are MDs and have a critical care specialty. The length of time practicing medicine ranged from three years to thirty-seven years. The average number of years practicing medicine for those using a DSS was 16.67 years, while the average for those not using a DSS was 17.75 years. Each category (use vs. non-use of DSS) had one physician practicing less than 10 years, two and three physicians practicing between 10 and 20 years respectively, and one physician practicing more than 20 years. Eight of the nine respondents answered the question about the hospital system where they worked or were affiliated in various ways, including “OUHSC”, “OU”, “OU Children’s”, and “Children’s Hospital”. Both answers of “OUHSC” and “OU” are referring to the University of Oklahoma Health Sciences Center. The answers “OU Children’s” and “Children’s Hospital” are both referring to the children’s hospital located on the University of Oklahoma Health Sciences Center campus. All answers are entities affiliated with the University of Oklahoma Medical Center (OU Medical). Table 7 shows a summary of the data discussed above.

Table 7

Years of Practice, Credentials, Specialty, Hospital System

Survey Question	Responses	Number of Responses
1. Years in Medicine	1-10 year	3 (33%)
	11-20 years	4 (44%)
	21-30 years	1 (11%)
	31-40 years	1 (11%)
2. Medical Credentials	MD	9 (100%)
3. Critical Care Specialty	Internal	2 (22%)
	Pediatrics	5 (56%)
	Pulmonary	1 (11%)
	Surgical	1 (11%)
4. Hospital System	Children’s Hospital	2 (22%)
	OU Children’s	1 (11%)
	OU	2 (22%)
	OUHSC	2 (22%)
	OU Medical System	1 (11%)
	No response	1 (11%)

Note. Percentages listed for Survey Questions 1 and 4 add up to 99% instead of 100% due to all decimals being less than .5 and rounding down.

Five of the nine physicians (56%) used a DSS. Of those, four indicated they used the DSS for diagnosis (80%). A fifth physician said they did not use the DSS for diagnosis (20%), however, on Question 16, they checked the box next to “I had several diagnoses for this patient, and I used (will use) this information to justify a choice,” indicating they did use the DSS to assist in diagnosis. All of the respondents who used a DSS used UpToDate. Each respondent who used a DSS also indicated that they found relevant information. None of the physicians indicated that the use of a DSS was required. Finally, each respondent who used a DSS indicated they used a DSS on a consistent basis, either weekly or monthly. Four of the physicians did not use a DSS and four gave the following reasons: “never available,” “unknown,” “I don’t know what that is,” and “I don’t know what a decision support system is.”

Diagnostic Error Rate

In chapter 3 the diagnostic error rate formula was mentioned as the number of changed DSS assisted diagnoses divided by the number of all DSS assisted diagnoses. The previous section established the total number (bottom of the equation) of DSS assisted diagnosis was five. Appendix B lists the two information assessment method (IAM) questions (4 and 5) and their answers used to determine diagnostic error. These questions are listed below.

4. Did you (will you) use this information to diagnose a specific patient?
   Yes/No/Possibly If Yes: Check all that Apply
   a. As a result of this information I managed (or will manage) this patient differently.
   b. I had several options for this patient, and I used (will use) this information to justify a choice.
   c. I did not know what to do, and I used (will use) this information to manage this patient.
   d. I thought I knew what to do, and I used this information to be more certain about the management of this patient.
   e. I used this information to better understand a particular issue related to this patient.

f. I used (will use) this information in a discussion with this patient, or with other health professionals about this patient.

g. I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change for this patient.

5. For this patient, did you observe (or do you expect) any health benefits as a result of applying this information? Yes/No/Possibly If Yes: Check all that Apply

   a. This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors).

   b. This information helped to prevent (will help to prevent) a disease or worsening of disease for his patient.

   c. This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient.

   d. This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention.

   e. This information helped to increase this patient's knowledge, or their family or home health aides' knowledge.

Table 8 lists the respondent's answers to these questions and whether or not they would have made a diagnostic error. It also lists the responses to questions concerning a follow-up visit (none were conducted) and what harm would have been caused if the diagnosis was not changed. It was determined that three of the five physicians using a DSS would have made a diagnostic error without the DSS. Therefore, the diagnostic error rate is 60% (diagnostic error rate = 3/5 = .6). Using the online calculator (https://www.surveysystem.com/sscalc.htm), with the population of thirty-one and a sample size of five, the confidence interval was forty-one. This indicates the true diagnostic error rate is between 19%-100%. Taking the lowest range of 19%, it is between the ranges listed in the literature for an overall 10%-15% error rate (Berner & Graber, 2008) and critical care diagnostic error rate as high as 28% (Winters et al., 2012).

Table 8

Survey Results for Questions Used to Determine Diagnostic Error

Respondent	IAM Response to Question 4	IAM Response to Question 5	Follow-Up Conducted?	Harm if Diagnosis not Changed	Diagnostic Error?
1	I used this information to better understand a particular issue related to this diagnosis				No
2	I used this information to better understand a particular issue related to this diagnosis	This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors),This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient.		Other treatment given	Yes
5	I thought I knew the diagnosis, and I used this information to be more certain about the diagnosis., I used this information to better understand a particular issue related to this diagnosis	This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient.			Yes
9	I used this information to better understand a particular issue related to this diagnosis	This information helped to decrease this patient's worries about a treatment, diagnostic procedures or preventative intervention			No
11	I had several diagnoses for this patient, and I used (will use) this information to justify a choice, I used this information to better understand a particular issue related to this diagnosis	This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors) This information helped to decrease this patient's worries about a treatment, diagnostic procedures or preventative intervention			Yes

Note. IAM = information assessment method. Gray cells indicate respondents skipped the question.

Table 9

DSS Usage and Belief in Reducing Diagnostic Error

Respondent	Frequency of Use	Reason No DSS Use	Will DSS Reduce Diagnostic Error?	Why/Why Not Reduce Error?
1	Weekly			
2	Weekly		Yes	A readily available tool could be used to confirm or deny a diagnosis, and certify a plan
3	Never	Never available	Yes	Drug Interactions
4	Never	Unknown	Yes	Evidence based
5	Monthly			
6	Never	I don’t know what a decision support system is	No	I don’t know enough to comment
7	Never	I don’t know what that is	Yes	Without knowing what you consider a support tool, it's difficult to say
9	Weekly		No	physicians will still have to look in the right direction usually just confirm diagnosis
11	Monthly		No	Maybe- it needs to be easily accessed and is currently dependent on self-realization of need to access by practioner.

Note. Gray cells indicate respondents skipped the question. Respondent 8 and 10 were duplicates that were excluded from the study.

Each physician, regardless of DSS use, was asked if they believed using a DSS would reduce diagnostic error. Seven of the nine physicians responded to this question. Four physicians believed use of a DSS would reduce diagnostic error (57%), while three did not (43%). Among the four physicians who believe a DSS would reduce diagnostic error only one (25%) had used a DSS. However, two of the three physicians who did not believe a DSS would reduce diagnostic error, had used a DSS (67%). Of those three, only one believed using a DSS would reduce diagnostic error. Physicians were asked why they believed or did not believe a DSS would reduce diagnostic error. Table 9 matches the data between the frequency of DSS use, reasons for not using a DSS, and opinions about the use of a DSS on diagnostic error.

Research Questions

This section presents the results of chi-square test of independence as well as the counternull value. When the lowest cell frequency was below five Fisher's exact probability was reported. If the probability of obtaining the observed results (*p*-value) is greater than 0.05 (95% confidence interval), then we cannot reject the null hypothesis. A medium (0.30) to large (0.40) value for the counternull means we cannot reject the alternate hypothesis because the counternull is associated with the alternate (or original) hypothesis and has the same *p*-value while "…provid[ing] an effect size value that is equally as likely to be true as the null effect size of .00" (Kramer & Rosenthal, 1999, p. 66). These rejections indicate that it is just as probable that Variable 1 is a factor in the occurrence of Variable 2 as it is that Variable 1 is NOT a factor in Variable 2. Additionally, the excluded questions listed in Table 6 in the "data coding and cleanup" section of chapter 3, is not listed in this chapter.

Research Question 1: Does the use of a decision support system during diagnosis reduce diagnostic error?

1A. What effect does the use of decision support systems during the diagnostic process by critical care physicians have on diagnostic error?

1Ai.H_1: The use of a decision support system by critical care physicians for diagnostic purposes is a factor in occurrence of diagnostic error.

1Ai.H_0: The use of a decision support system by critical care physicians for diagnostic purposes is not a factor in occurrence of diagnostic error.

No statistical significance was found and failed to reject both the null and alternate hypotheses ($p = 1 > 0.05$, phi = -0.408, $n = 5$, counternull = 0.71). The negative phi score indicates that as the use of decision support systems (DSS) during the diagnostic process increases, diagnostic error decreases. With only five samples, more data is needed to determine statistical significance.

A second chi-square test was run using the physicians belief in the ability of a DSS to reduce diagnostic error as the dependent variable. No statistical significance was found and failed to reject both the null and alternate hypotheses ($p = 1 > 0.05$, phi = 0.25, $n = 5$, counternull=0.48). Table 10 lists the results of both statistical tests. The positive phi score indicates that as the use of a DSS during the diagnostic process increases, the belief in the ability of a DSS to reduce diagnostic error also increases.

Table 10

Research Question 1A Results

Hypothesis	Dependent Variable	*n*	*p*	phi	counternull	ES rating
1Ai.H	Diagnostic Error	5	1	-0.408	0.71	Large
1Ai.H	Belief DSS Reduce Error	5	1	0.25	0.48	Medium

Note. n is the sample size, p is the probability of obtaining the observed results, phi is the phi coefficient, and ES rating, is the effect size of the counternull value.

1B. How does critical care physician attributes (medical credentials, type of specialty, and time practicing medicine) impact diagnostic error?

1Bii.H_1: Having an internal critical care specialty is a factor in the occurrence of diagnostic error.

1Bii.H_0: Having an internal critical care specialty is not a factor in the occurrence of diagnostic error.

1Biii.H_1: Having a pediatrics critical care specialty is a factor in the occurrence of diagnostic error.

1Biii.H_0: Having a pediatrics critical care specialty is not a factor in the occurrence of diagnostic error.

1Bv.H_1: Having a surgical critical care specialty is a factor in the occurrence of diagnostic error.

1Bv.H_0: Having a surgical critical care specialty is not a factor in the occurrence of diagnostic error.

1Bvii.H_1: The amount of time a physician has practiced medicine is a factor in the occurrence of diagnostic error.

1Bvii.H_0: The amount of time a physician has practiced medicine is not a factor in the occurrence of diagnostic error.

For all the Question 1B hypotheses the resulting crosstab was greater than a 2x2 table and therefore, the chi-squared value was used instead of the Fishers exact test. All the physicians had a critical care specialty and therefore, the existence of the specialty was not being analyzed, but rather the type of specialty. For hypotheses ii, iii, and v, none of the critical care specialties were statistically significant, failing to reject both the null and alternate hypotheses.

- Internal Critical Care Specialty ($p = 1 > 0.05$, phi = -0.167, $n = 5$, counternull = 0.33)
- Pediatric Critical Care Specialty ($p = 1 > 0.05$, phi = -0.167, $n = 5$, counternull = 0.33)
- Surgical Critical Care specialty ($p = 1 > 0.05$, phi = 0.408, $n = 5$, counternull = 0.71)

The negative phi scores for internal and pediatric critical care specialties indicate that as the number of physicians with those specialties increase, diagnostic error decreases. The opposite is true for the surgical critical care specialty. However, a larger sample size is needed for a statistically significant result.

Looking at a physician's belief in the ability of a DSS to reduce diagnostic error also resulted in no statistical significance and failure to reject the null hypothesis (statistical results listed below). However, the counternull was only large for the surgical critical care specialty. We cannot reject the alternate hypothesis for surgical, but can reject it and accept the null hypothesis for both internal and pediatric critical care specialties.

- Internal Critical Care Specialty (p = 1 > 0.05, phi = 0.06, n = 9, counternull = 0.12)
- Pediatric Critical Care Specialty (p = 1 > 0.05, phi = -0.1, n = 9, counternull = 0.2)
- Surgical Critical Care specialty (p = 1 > 0.05, phi = -0.316, n = 9, counternull = 0.58)

The negative phi scores for pediatric and surgical critical care specialties indicate that as the number of physicians with those specialties increase, the belief in the ability of a DSS to reduce diagnostic error decreases. The opposite is true for the internal critical care specialty. However, a larger sample size is needed for a statistically significant result.

Looking at time spent practicing medicine in ten-year increments (1Bvii), no statistical significance was found (p = .329 > 0.05, phi = 0.667 n = 5, counternull = 0.92), failing to reject both the null and alternate hypothesis. The positive phi score shows that as the time spent practicing medicine increases so does the rate of diagnostic error. More data is needed for a statistically significant result.

Considering a physician's belief in the ability of a DSS to reduce diagnostic error, there was no statistically significant result (p = 0.353, phi = 0.602, n = 9, counternull = 0.88), failing to reject both the null and alternate hypotheses. Table 11 lists the results for all the 1B hypotheses. The positive phi value indicates that as the time spent practicing medicine increases so does the belief in the ability of a DSS to reduce diagnostic error.

Table 11

Research Question 1B Results

Hypothesis	Dependent Variable	*n*	*p*	phi	counternull	ES rating
1Bii.H	Diagnostic Error	5	1	-0.167	0.33	Medium
1Bii.H	Belief DSS Reduce Error	9	1	0.06	0.12	Small
1Biii.H	Diagnostic Error	5	1	-0.167	0.33	Medium
1Biii.H	Belief DSS Reduce Error	9	1	-0.1	0.2	Small
1Bv.H	Diagnostic Error	5	1	0.408	0.71	Large
1Bv.H	Belief DSS Reduce Error	9	1	-0.316	0.58	Large
1Bvii.H	Diagnostic Error	5	0.329	0.667	0.92	Large
1Bvii.H	Belief DSS Reduce Error	9	0.353	0.602	0.88	Large

Note. n is the sample size, p is the probability of obtaining the observed results, phi is the phi coefficient, and ES rating, is the effect size.

Research Question 2: How are decision support systems used by critical care physicians?

2A. For what purposes are critical care physicians using a DSS?

2Ai.H_1: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is a factor in the occurrence of diagnostic error.

2Ai.H_0: Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is not a factor in the occurrence of diagnostic error.

2Aii.H_1: Critical care physician use of a DSS to fulfill a personal educational objective is a factor in the occurrence of diagnostic error.

2Aii.H_0: Critical care physician use of a DSS to fulfill a personal educational objective is not a factor in the occurrence of diagnostic error.

Neither Hypothesis i or ii were statistically significant ($p = 1 > 0.05$, phi = -0.408, $n = 5$, counternull = 0.71; $p = 1 > 0.05$, phi = 0.408, $n = 5$, counternull = 0.71) and failed to reject both the null and alternate hypotheses. Hypothesis i had a negative phi indicating that as use of a

DSS to answer a clinical question increased, diagnostic error decreased. Hypothesis ii had a positive phi indicating as use of a DSS to fulfill a personal objective increased so did diagnostic error. More data is needed to confirm statistical significance.

A statistically significant result was found, when analyzing the belief in the ability of a DSS to reduce diagnostic error. As the use of a DSS to answer a clinical question increases, the belief in the ability of a DSS to reduce diagnostic error decreases. The data was statistically significant ($p = 0.048 < 0.05$, phi = -0.8, $n = 9$, counternull = 0.97) and supported the rejection of the null hypothesis and failure to reject the alternate hypothesis.

No statistical significance was found when looking at the belief in the ability of a DSS to reduce diagnostic error and using a DSS to fulfill a personal objective ($p = 0.44 > 0.05$, phi = 0.395, $n = 9$, counternull = 0.69), failing to reject both the null and alternate hypotheses. See Table 12 for a full list of results for Question 2A. The positive phi score indicated that as the use of a DSS to fulfill a personal object increased the belief in the ability of a DSS to reduce diagnostic error also increased. More data is needed for statistically significant results.

Table 12

Research Question 2A Results

Hypothesis	Dependent Variable	*n*	*p*	phi	counternull	ES rating
2Ai.H	Diagnostic Error	5	1	-0.408	0.71	Large
2Ai.H	Belief DSS Reduce Error	9	0.048	-0.8	0.97	Large
2Aii.H	Diagnostic Error	5	1	0.408	0.71	Large
2Aii.H	Belief DSS Reduce Error	9	0.44	0.395	0.69	Large

Note. n is the sample size, p is the probability of obtaining the observed results, phi is the phi coefficient, and ES rating, is the effect size.

2B. How often are critical care physicians using DSS?

2Bi.H_1: The frequency of critical care physicians use of a DSS is a factor in the occurrence of diagnostic error.

2Bi.H_0: The frequency of critical care physicians use of a DSS is not a factor in the occurrence of diagnostic error.

The hypothesis had no statistical significance ($p = 0.4 > 0.05$, phi = -0.667, $n = 5$, counternull = 0.92) and was unable to reject both the null and alternate hypotheses. The negative phi score indicated the more often the physician used a DSS the lower the diagnostic error rate. More data is needed for a statistically significant result.

Looking at belief in the ability of a DSS to reduce diagnostic error. There was no statistical significance ($p = 0.196 > 0.05$, phi = 0.602, $n = 9$, counternull = 0.88) and failed to reject both the null and alternate hypotheses. Table 13 lists the results for Question 2B. The positive phi score shows the more often a physician used a DSS the greater their belief in the ability of a DSS to reduce diagnostic error. Again, more data is needed for a statistically significant result.

Table 13

Research Question 2B Results

Hypothesis	Dependent Variable	*n*	*p*	phi	counternull	ES rating
2Bi.H	Diagnostic Error	5	0.4	-0.667	0.92	Large
2Bi.H	Belief DSS Reduce Error	9	0.196	0.602	0.88	Large

Note. n is the sample size, p is the probability of obtaining the observed results, phi is the phi coefficient, and ES rating, is the effect size.

2D. The outcome of DSS information obtained by critical care physicians may change their practice. How do these changes impact diagnostic error?

2Di. H_1: Physicians practice changed or improved from use of DSS information is a factor in the occurrence of diagnostic error.

2Di. H_0: Physicians practice changed or improved from use of DSS information is not a factor in the occurrence of diagnostic error.

$2Dii.H_1$: Learning something new from the DSS information is a factor in the occurrence of diagnostic error.

$2Dii.H_0$: Learning something new from the DSS information is not a factor in the occurrence of diagnostic error.

$2Dii.H_1$: Confirming correct actions with the DSS information is a factor in the occurrence of diagnostic error.

$2Diii.H_0$: Confirming correct actions with the DSS information is not a factor in the occurrence of diagnostic error.

$2Div.H_1$: Being reassured by the DSS information is a factor in the occurrence of diagnostic error.

$2Div.H_0$: Being reassured by the DSS information is not a factor in the occurrence of diagnostic error.

$2Dv.H_1$: Being reminded of something already known by the DSS information is a factor in the occurrence of diagnostic error.

$2Dv.H_0$: Being reminded of something already known by the DSS information is not a factor in the occurrence of diagnostic error.

No statistical significance was found for any of the Question 6 hypotheses, failing to reject all the null and alternate hypotheses. Table 14 summarizes the results with both dependent variable of diagnostic error and belief in the ability of a DSS to reduce diagnostic error. The hypotheses with negative phi scores indicate a reduction in diagnostic error as the particular outcome from using a DSS increased. However, more data is needed for statistically significant result.

No statistical significance was found when looking at a physician's belief in the ability of a DSS to reduce diagnostic error failing to reject the null hypothesis. Table 14 shows that hypotheses i-iv all had medium to large counternull values, also failing to reject the alternate hypothesis. Hypothesis v, dealing with the outcome of being reminded of something the physician already knew had a small counternull indicating that acceptance of the null hypothesis stands. Hypotheses i-iv all had negative phi's which indicated as the outcome from using a DSS increased the belief in the ability of a DSS to reduce diagnostic error decreased. More data is needed for a statistically significant result.

Table 14

Research Question 2D Results

Hypothesis	Dependent Variable	*n*	*p*	phi	counternull	ES rating
2Di.H	Diagnostic Error	5	1	-0.167	0.33	Medium
2Di.H	Belief DSS Reduce Error	9	0.444	-0.478	0.78	Large
2Dii.H	Diagnostic Error	5	1	0.167	0.33	Medium
2Dii.H	Belief DSS Reduce Error	9	1	-0.158	0.31	Medium
2Diii.H	Diagnostic Error	5	0.4	0.612	0.89	Large
2Diii.H	Belief DSS Reduce Error	9	0.524	-0.35	0.63	Large
2Div.H	Diagnostic Error	5	0.4	0.612	0.89	Large
2Div.H	Belief DSS Reduce Error	9	0.524	-0.35	0.63	Large
2Dv.H	Diagnostic Error	5	1	-0.167	0.33	Medium
2Dv.H	Belief DSS Reduce Error	9	1	0.06	0.12	Small

Note. n is the sample size, p is the probability of obtaining the observed results, phi is the phi coefficient, and ES rating, is the effect size.

Summary

This chapter presented the survey results, calculated the diagnostic error rate based on the data, and presented the statistical results for each research question not excluded from the study. The overall results of the study indicate further data is needed to make statistically significant results. However, the large counternull values presented demonstrated that the alternate hypothesis is just as likely to be true as the null hypothesis. While the sample size is small and cannot be statistically significant, it does not preclude them from being practically significant. The next chapter will discuss the practical significance further.

CHAPTER 5

FINDINGS, DISCUSSION, LIMITATIONS, FUTURE RESEARCH, AND SUMMARY

Findings

While statistical significance is important, Kramer (1999) states that effect sizes "… are essential to determining the practical importance of a study." (p. 76). The counternull was calculated as the effect size for all alternate hypotheses. The findings for each of the two main research questions, including the practical results with large effect sizes, are discussed below and summarized in Table 15. On further analysis of the data, another dependent variable was identified: the physician's belief in the ability of a DSS to reduce diagnostic error. These findings are also presented in this chapter but were not included in Table 15, which discusses hypotheses and conclusions. Next the discussion of the conclusions, limitations, future research directions, and summary of the chapter are presented.

Table 15

Hypothesis and Conclusions

Number	Hypothesis	Conclusions
1Ai.H	The use of a decision support system by critical care physicians for diagnostic purposes is a factor in occurrence of diagnostic error.	Use of DSS by critical care physicians during the diagnostic process can reduce diagnostic error by up to 60%. 56% of critical care physicians are using a DSS.
1Bi.H	The type of medical credentials is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
1Bii.H	Having an internal critical care specialty is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
1Biii.H	Having a pediatrics critical care specialty is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
1Biv.H	Having a pulmonary critical care specialty is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.

(table continues)

Number	Hypothesis	Conclusions
1Bv.H	Having a surgical critical care specialty is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
1Bvi.H	Having an anesthesiology critical care specialty is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
1Bvii.H	The amount of time a physician has practiced medicine is a factor in the occurrence of diagnostic error.	As time spent practicing medicine increases, diagnostic error decreases.
1Ci.H	The relevance of information provided by the DSS is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Ai.H	Critical care physician use of a DSS to address a clinical question (problem) about a specific patient is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
2Aii.H	Critical care physician use of a DSS to fulfill a personal educational objective is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
2Aiii.H	Critical care physician use of a DSS to satisfy curiosity or for personal interest is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Aiv.H	Critical care physician use of a DSS to look up something forgotten is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Av.H	Critical care physician use of a DSS to share information with a patient, their family, or home health aides is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Avi.H	Critical care physician use of a DSS to exchange information with other health professionals is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Bi.H	The frequency of critical care physicians use of a DSS is a factor in the occurrence of diagnostic error.	As the frequency of DSS use increases, diagnostic error decreases. More frequent use of a DSS may improve overall diagnostic skills.
2Ci.H	The use of DSS by critical care physicians with critically ill patients is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Cii.H	The use of DSS by critical care physicians with non-critically ill patients is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.

(table continues)

Number	Hypothesis	Conclusions
2Di.H	Physicians practice changed or improved from use of DSS information is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
2Dii.H	Learning something new from the DSS information is a factor in the occurrence of diagnostic error.	As the use of a DSS to learn something new increased, diagnostic error increased.
2Diii.H	Confirming correct actions with the DSS information is a factor in the occurrence of diagnostic error.	As the use of a DSS to confirm something already known increased, diagnostic error increased.
2Div.H	Being reassured by the DSS information is a factor in the occurrence of diagnostic error.	AS the use of a DSS to reassure a physician increased, diagnostic error increased.
2Dv.H	Being reminded of something already known by the DSS information is a factor in the occurrence of diagnostic error.	No conclusions were drawn due to lack of data.
2Dvi.H	Being dissatisfied with the DSS information is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Dvii.H	Having an issue with the way information is presented in the DSS is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Dviii.H	Disagreeing with information in the DSS is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.
2Dix.H	The DSS information being potentially harmful is a factor in the occurrence of diagnostic error.	Excluded as discussed in chapter 3.

Note. Does not include conclusions based on physician's belief in the ability of a DSS to reduce diagnostic error.

Research Question 1: Does the use of a decision support system during diagnosis reduce diagnostic error?

Findings indicate that five out of nine critical care physicians use a DSS (56%). Furthermore, this study found the critical care physician diagnostic error rate to be 60%. A confidence interval of 41 makes the diagnostic error rate a range of 19%-100% with a 95% confidence level. While this represents a large range, existing literature estimates the critical care diagnostic error rate to be as high as 28% (Winters et al., 2012), falling within the range found in this study. The large effect size (counternull = 0.71) indicates practical support for a relationship between the use of a DSS and diagnostic error. From a practical viewpoint, three out of five critical care physicians (60%) practicing at the University of Oklahoma Health Sciences Center avoided a diagnostic error by using a decision support system (DSS), UpToDate in this case. The negative phi (-.0408) indicates that as the use of a decision support system during the diagnostic process increases, diagnostic error decreases. Follow-up visits could have confirmed these findings, but unfortunately the physicians either did not have follow-up visits or just failed to provide the information in the survey. Despite this, the results do have practical importance.

Finally, as the use of a DSS during diagnosis increases, a physician's belief in the ability of a DSS to reduce diagnostic error also increases (counternull = 0.48, phi = 0.25). Three out of four physician's (80%) used the DSS for diagnostic purposes. As was discussed in the results section, despite the fifth physician indicating they did not use the DSS for diagnosis, other survey responses indicated they did. However, the data for the statistics were still coded with the physician's original error. That particular physician left the belief question blank and was assumed they did not believe use of a DSS would reduce diagnostic error. Additionally, there was only one of the physicians using a DSS for diagnosis that believe the use of a DSS would reduce diagnostic error. Such a small sample size skews the statistical results and looking at the data only 20% of physicians (1) using a DSS believed it could reduce diagnostic error. Excluding the assumed "No's" on the belief question increases the percentage of physicians using a DSS and believing use will reduce diagnostic error to 33%. Either percentage points to increased use of a DSS for diagnosis leading to a decreased belief in use of the DSS to reduce error. A discussion of why appears later in the chapter.

There were no conclusions of practical importance drawn from observing the effect of internal, pediatrics, or surgical critical care specialties on the rate of diagnostic error. Despite medium to large counternulls (0.33, 0.33, and 0.71 respectively) there were too few physicians in each specialty using a decision support system (DSS) (internal = 2, pediatrics = 2, and surgical = 1) to determine any trends. Examining the belief in the ability of a DSS to reduce diagnostic error, the only specialty with a large counternull (0.58), was surgical. However, there was only one physician with a surgical specialty, which again was too small a sample size to draw any conclusions.

Table 16

Data Coding for Time Spent Practicing Medicine

Diagnostic Error	Years Practicing Medicine	Coded in 10-year increments
Yes	3	1
Yes	13	2
Yes	20	2
No	20	2
No	27	3

Note. Coding 1 = 0-10yrs, 2 = 11-20yrs, 3 = 20-30yrs

A conclusion of practical importance was as time spent practicing medicine increases, diagnostic error decreases. This conclusion was based on the following data: three out of five physicians, who would have had a diagnostic error without a DSS had twenty years or less experience practicing medicine, while the remaining two physicians had twenty years or more experience. However, this conclusion is contradicted by the positive phi (0.667) and large counternull (0.92), which suggests as time practicing medicine increases, so does diagnostic error. The statistics are most likely skewed by the requirements of the chi-square*d test* for transforming interval variables (time spent practicing medicine) into categorical variables. Table 16 shows the coding data and how it aligns with actual years spent practicing medicine. The table clearly shows a trend of diagnostic error decreasing the longer a physician has practiced medicine.

When considering the belief in the ability of a DSS to reduce diagnostic error in relation to time spent practicing medicine, the data seems to be evenly spread out. Physicians in this study who have practiced medicine for 3, 10, 15, and 37 years believe in the ability of a DSS to reduce diagnostic error, while physicians practicing medicine for 9, 13, and 20 years believe that the use of a DSS will not reduce diagnostic error. The positive phi (0.602) and large counternull (0.88), which indicates as time practicing medicine increases, so does the belief in the ability of a DSS to reduce diagnostic error. While it's difficult to see this trend when examining the raw data, there is no observable trend in the opposite direction. The fact that physicians practicing for 20 and 27 years left the belief question blank but was coded as a "No" could have pushed the statistical test toward a positive trend.

If diagnostic error decreases as time in medicine increases, this could explain why as the use of a DSS for diagnosis increases, belief in the ability of DSS to reduce diagnostic error decreases. As physicians spend more time practicing medicine, they acquire more practical experience and may become better at recognizing symptoms and making correct diagnoses. As they become better at diagnosing patients, information contained within a DSS may be more likely to confirm their original diagnosis. If a DSS is more often confirming diagnoses rather than suggesting alternate diagnoses, a physician's belief in the usefulness of DSS may decrease.

Existing literature supports this reasoning, as overconfidence is often listed as a reason for diagnostic error (Graber, Franklin, & Gordon, 2005; Schiff et al., 2005; Berner & Graber, 2008; Ely, Graber, & Croskerry, 2011; Ely, Kaldjian, & D'Alessandro, 2012).

Research Question 2: How are decision support systems used by critical care physicians?

One statistically significant conclusion from the Question 2 hypotheses was identified: when the use of a DSS to answer a clinical question increases, the belief in the ability of a decision support system (DSS) to reduce diagnostic error decreases (phi = -0.8, counternull = 0.97). If DSS use decreases diagnostic error, this finding is counterintuitive. Once again, this result can possibly be explained by time spent in medicine increasing expertise both in medicine and in the use of a DSS. Therefore, the more often they use a DSS to answer a clinical question, the more often they could be receiving confirmation on what they already believe or know. No other statistically significant or practical conclusions were reached when evaluating the use of a DSS to answer a clinical question or fulfill a personal objective.

Another conclusion drawn from an analysis of the data is that as frequency of DSS use increases, diagnostic error decreases (phi = -0.667, counternull = 0.92). The two critical care physicians who used a DSS on a monthly basis had a diagnostic error rate of 100%. The three critical care physicians who used a DSS more often (weekly) had a diagnostic error rate of 33%. This data supports the alternative hypothesis ($2Bi.H_1$). This data also suggests that more frequent use of a DSS may improve overall diagnostic skills.

A third interesting observation from this study is increased frequency of DSS use leads to a decrease in the belief of a DSS to reduce diagnostic error. Physicians who never used a DSS were more likely to believe in the ability of a DSS to reduce diagnostic error. Three out of four physicians (75%) who never used a DSS believed use of a DSS would reduce diagnostic error, while only one out of five physicians who used a DSS (20%) believed use of a DSS would reduce diagnostic error. The positive phi (0.602) and large counternull (0.88) contradict this observation and indicate that as the frequency of DSS use increases, so does the belief in the ability of a DSS to reduce diagnostic error. This contradiction is due to data coding. When just looking at DSS usage and DSS non-usage (two categories), it has already been discussed why as use increases belief decreases. However, with frequency of use, the resulting survey data was coded into three categories: never used, monthly use, and weekly use. Within the monthly and weekly categories, there is an outlier of one physician who used the DSS on a weekly basis believing that use of a DSS could reduce diagnostic error. With a small sample size, this is enough to skew those results into a positive relationship. The final conclusion, would be to accept the observed negative relationship.

Three additional conclusions of potential importance were supported by positive phi values and medium to large counternulls:

- As information from a DSS was used to learn something new, diagnostic error was increased (phi = 0.167, counternull = 0.33).
- As information from a DSS was used to confirm something already known, diagnostic error was increased (phi = 0.612, counternull = 0.89).
- As information from a DSS was used to reassure the physician, diagnostic error was increased (phi = 0.612, counternull = 0.89).

A closer look at the data shows that three of the four physicians that checked confirmation also had a diagnostic error. Three of the four physicians that checked they were reassured also had diagnostic errors. To determine a diagnostic error, the physicians would have had to answer other survey questions in a way that indicated they changed the diagnosis.

If the DSS information confirmed something or reassured the physicain, then why would they change their diagnosis? More than likely, the DSS information confirmed and/or reassured the physicians about something related to their diagnosis, but not the final diagnosis itself. This assumption is further supported by the fact that the three physicians who had a diagnostic error indicated that they both confirmed something and were reassured. This included two of the physicians learning something new, one of them changing or improving their practice, and one being reminded of something they already knew. Overall, the physicians that had a diagnostic error checked more items of impact than those that did not have an error. While there seems to be a relationship between the impact on practice and diagnostic error, no particular impact can be singled out.

When examining belief in the ability of a DSS to reduce diagnostic error, the following conclusions of practical importance were observed:

- As information from a DSS was used to learning something new, the belief in the ability of a DSS to reduce diagnostic error decreased (phi = -0.158, counternull = 0.31).
- As information from a DSS was used to confirm something already known, the belief in the ability of a DSS to reduce diagnostic error decreased (phi = -0.35, counternull = 0.63).
- As information from a DSS was used to reassure the physician, the belief in the ability of a DSS to reduce diagnostic error decreased (phi = -0.35, counternull = 0.63).

If decision support systems reduce diagnostic error, then these findings once again seem counterintuitive. As discussed before, the more often a physician confirms current knowledge the more likely they may start to believe that a DSS has no use. This could also be true for when the information reassures the physician. However, in the case of a physician learning something new, why would belief still decrease? This could be a result of how the data was coded. There were three physicians that indicated they learned something new. Of these, one believed a DSS could reduce diagnostic error and one did not. The third physician left the question blank. An assumption was made with the data that a blank response indicated that the corresponding physician did not believe in the ability of a DSS to reduce diagnostic error. Therefore, no conclusions can be drawn concerning physicians learning something new from the DSS information.

Due to a small sample size, statistical significance is difficult to prove in this study. However, practical importance based on effect size (Kramer, 1999) and analysis of the data led to the following findings:

- The following factors can lead to a decrease in diagnostic error by critical care physicians:
  - Increase in use of a DSS during the diagnostic process
  - Increase in the length of time a physician spends practicing medicine
  - Increase in the frequency of DSS use
  - Decrease in the use of a DSS to learn something new
  - Decrease in the use of a DSS to confirm something already known
  - Decrease in the use of a DSS to reassure a physician
- The following factors can lead to a decrease in a critical care physician's belief that the use of a DSS can reduce diagnostic error:
  - Increase in use of a DSS during the diagnostic process
  - Decrease in the length of time a physician spends practicing medicine
  - Increase in the frequency of DSS use
  - Increase in the use of a DSS to answer clinical questions
  - Increase in the use of a DSS to confirm something already known

- Increase in the use of a DSS to reassure a physician

These findings answer the two major research questions. Does the use of a decision support system during diagnosis reduce diagnostic error? Yes, according to the data from this study the use of a DSS during diagnosis by a critical care physician reduces diagnostic error by up to 60%. This reduction increases with frequency of DSS use and with time spent practicing medicine. How are decision support systems used by critical care physicians? Critical care physicians are using DSS to answer clinical questions and fulfill personal educational objectives. When physician's use DSS for these purposes they learn something new, confirm something already known, and/or reassure themselves. Unfortunately, this does not result in a reduction of diagnostic error. All findings are summarized above and listed in Table 15.

Discussion

There were three major conclusions of this study:

1. The use of a decision support system during diagnosis by a critical care physician can reduce diagnostic error by up to 60%.
2. Five out of nine (56%) critical care physicians are using a DSS during diagnosis to learn something new, confirm something they already knew, and/or reassure themselves.
3. The increased use of a DSS by critical care physicians during diagnosis can lead to a decrease in the belief of the ability of a DSS to reduce diagnostic error.

The first conclusions, the use of a decision support system during diagnosis by a critical care physicians can reduce diagnostic error by up to 60%, supports the original hypothesis that using a DSS as part of the diagnostic process would reduce diagnostic error. However, this result is skewed because four of the five physicians who used a DSS did so as part of diagnosis. The physician who indicated the DSS use was not part of diagnosis also believed the DSS would not reduce diagnostic error. However, this same physician also stated that they used the DSS to justify a choice between several diagnoses, indicating they actually had used the DSS as part of diagnosis. This not only contradicts the response to the question concerning the physician's use of the DSS in diagnosis, but also indicates that without the DSS, a diagnostic error would have occurred. More data is needed to apply these conclusions across the spectrum of physicians and hospital systems.

The second conclusion was 56% of critical care physicians are using a DSS to learn something new, confirm something they already knew, and/or to reassure themselves. The majority of physicians checked multiple reasons for using a DSS. Two out of the five physicians (40%) using a DSS checked all three reasons, while only one physician (20%) checked just one reason. Additionally, UpToDate was the DSS used by all the critical care physicians. One reason for this may be due to the University of Oklahoma Health Sciences Center Library providing access to UpToDate. It was also encouraging to see that the physicians who indicated their use of a DSS did so on a consistent basis, even when not required.

The third and final conclusion is that the use of a decision support system (DSS) by critical care physicians during diagnosis can lead to a decrease in their belief in the ability of a DSS to reduce diagnostic error. Belief in the use of a DSS to reduce diagnostic error is actually higher among those who have never used a DSS (75%). As intimated in previous paragraphs, part of the reason using a DSS can reduce the belief in its ability to reduce diagnostic error may be the increased diagnostic abilities of the physician over time. With more experience physicians may gain additional practical knowledge and become more adept in the diagnostic process. A logical assumption would be that improved diagnostic skills may lead to more frequent diagnostic confirmation from a DSS. However, it can also lead to overconfidence, which has been explored in existing literature as a reason for diagnostic error (Berner & Graber, 2008). One physician surveyed in this study said they “[p]refer to rely on my clinical acumen.” While this comment was made the second time a respondent completed the survey and the data points discarded, the comment is still relevant and supports the theory of overconfidence. This potential overconfidence in a physician’s own knowledge and skill may be so strongly held that it could explain why physicians in this study stated that they did not use the DSS for diagnosis, but later stated that they used the information provided by the DSS to change a diagnosis. Despite this contradictory data, two out of three physicians (67%) who use DSS believe it will not reduce diagnostic error. Again, more data is needed to apply these conclusions across the spectrum of physicians and hospital systems.

Limitations

Overconfidence in one’s intuition may help to explain physicians’ willingness to respond to the question regarding belief in the ability of a decisions support system (DSS) to reduce diagnostic error despite indicating confusion about what a DSS actually is. Three of the four physicians (75%) in this study who indicated that they do not use a DSS also indicated they did not know what a DSS was but still answered the belief question. Of these three physicians, two indicated a DSS would decrease diagnostic error (see Table 9). This was most likely impacted by the absence of a definition of a DSS at the beginning of the survey. When the survey was being designed, it was believed the question listing DSS names (UpToDate, Dynamed, Isabel, etc.) would trigger the understanding for physicians. However, when the survey was translated into Qualtrics and logic flow was added, only those physicians indicating they had used a DSS were given the question listing DSS names. The question asking whether or not use of a DSS could reduce diagnostic error came at the end of the survey. Physicians' views on use of a DSS may have been impacted in the course of answering previous questions and seeing the options about how practice and diagnosis changed due to information from the DSS. Despite these limitations, this study can set the stage for future research.

These conclusions and limitations contribute to the body of knowledge surrounding the understanding of the use of a DSS and diagnostic error rates. Additionally, the conclusions illustrate the need for physicians in critical care to be trained in the use of a DSS for diagnostic purposes as well as the potential impacts on patient care that DSS can have. Finally, the conclusions presented indicate that libraries and clinics should continue to provide access to DSS.

Future Research

There are multiple areas in which the current research methodology could be improved for future research. The first area would be improvements to the research instrument. One improvement would be to conduct the surveys in person instead of online. The in-person surveys would rule out any duplication and would also allow for follow-up questions to any open-ended questions. Follow-up questions would help to ensure an understanding of the physician's point of view.

Clearly defining a DSS and clarifying its use in differential diagnosis would generate a greater understanding of the diagnostic tool, thus increasing reliable data points. Another improvement would be to expand the survey to included open-ended questions about impact on practice. If physicians indicate that their practice was improved and that they gained new knowledge or understanding, it would useful to question how the new knowledge was acquired and what the new understanding entailed. This would help clarify whether information from a DSS w related directly to making a diagnosis or just contributed to learning something new about the existing diagnosis.

The second area of methodological improvement would be to expand the sample size and to conduct the surveys with the same physicians at multiple points in time. This would allow for calculating an individual physicians diagnostic error rate over time and with multiple patients. It would also produce data that indicates the frequency of use and non-use of a DSS in the physician's diagnoses. Many more data points would be generated in a longitudinal study even with a smaller group of physicians. Finally, this type of research should be conducted in other specialties to understand the use of DSS in the diagnostic process and reduction of diagnostic error. Expanding the research to include areas beyond critical care might discover if specialties (e.g. critical care versus family medicine) with lower diagnostic error rates are using DSS more frequently than those with higher diagnostic error rates.

Future research should focus in the following key areas. The first area is the inclusion of a DSS in the diagnostic process. While the findings of this research suggest using a DSS during the diagnostic process will lower the occurrence of diagnostic error, the findings are not definitive and further research is needed for replication and confirmation. If the use of a DSS can reduce diagnostic error, why is the rate of DSS use not higher? One area to focus on is the relationship between physician confidence levels in their diagnostic process and their willingness to use a DSS as part of that process. Are confidence levels lowering the rate of DSS use? If as the data suggests, some physicians are using the DSS for diagnostic purposes but are not seeing it as a part of diagnosis or are not believing that there is a relationship between its use and diagnostic error, can bridging this gap between practice and belief increase DSS usage?

The second key area for future researchers to explore are the reasons why physicians are not using a decision support system (DSS). Are all physicians aware of the DSS available to them? Are physicians trained in the use of a DSS? How long does it take a physician to become proficient in the use of a DSS? If the physician is not proficient in the use, will the DSS still help reduce diagnostic error? If physicians are proficient, are they more likely to get data from the DSS that confirms their diagnosis? If so, are they more likely to stop using the DSS? All of these are important questions to answer in order to not only determine the usefulness of a DSS in relation to diagnostic error, but also to provide insight on how to encourage physicians to use a DSS more frequently. Ultimately, the answers to these questions will assist librarians and health systems in developing an understanding of how to advertise the existence of a decision support system, how to make it available, and how to provide training for physicians as needed.

Summary

This chapter examined the findings, provided a discussion of those findings, and delivered questions to direct future research. The overall conclusions of the study indicate further data is needed to make statistically significant results. However, from a practical viewpoint, the data does indicate that original diagnoses were changed 60% of the time based on data provided by the DSS. In addition, the data shows that the more frequently a physician used a DSS, the more likely they were to change the diagnosis. This assumes that if the physician in question had not changed their diagnosis, it would have been a diagnostic error. Finally, all physicians using a DSS indicated the information found was relevant. Clearly more research is needed, but this study lays the foundation for further exploration of using a DSS to reduce diagnostic error.

APPENDIX A

LITERATURE REVIEW MATRIX

The literature review matrix covers the twenty-three studies identified as covering the topic of DSS and diagnosis. The matrix lists the Citation, Study Setting, Type of Study, Topic, DSS Used, and Conclusion. The table is sorted alphabetically by topic.

Citation	Study Setting	Type of Study	Topic	DSS Used	Conclusion
Belard et al., 2017	Critical and Surgical Care	Systematic Review	Assess current state of DSS in surgical and critical care	n/a	DSS need to be further developed for individualized precision diagnostics
DeBusk, Miller, & Raby, 2010	Emergency Department	Sample Cases	Assess DSS efficacy in classifying acute coronary syndrome as low or high risk	In-House Development	DSS could be used for a provisional diagnosis
Bond et al., 2012	n/a	Sample Cases	Develop DSS evaluation criteria for using DSS in diagnosis	Dxplain, Isabel, Diagnosis Pro, & PEPID	Should use DXPlain and Isabel
Lindgaard, Pyper, Frize, & Walker, 2009	Pediatrics	Sample Cases	Developing a DSS	Resident DSS	DSS should list the probability of each diagnosis
Cahan & Cimino, 2017	n/a	n/a	Developing a DSS	n/a	Need to develop DSS that has real-time sharing of patient structured patterns and clinical notes
Crowley et al., 2013	Dermatology	Sample Cases	Developing a DSS	n/a	Search satisficing and availability were the most frequent biases to address.
Elkin et al., 2010	General Medicine area of Hospital	Live Setting	DSS as a means to reducing healthcare costs	DXplain	DSS could reduce costs
El-Kareh, Hasan, & Schiff, 2013	n/a	Systematic Review	DSS and Diagnosis	n/a	Further research needs to be completed in clinical settings
Garg et al., 2005	n/a	Systematic Review	DSS and Diagnosis	n/a	DSS contained correct diagnosis majority of the time
Sim et al., 2001	n/a	Systematic Review	DSS and Diagnosis	n/a	Further research needs to be completed in clinical settings
Trowbridge & Weingarten, 2001	n/a	Systematic Review	DSS and Diagnosis	n/a	Further research needs to be completed in clinical settings

Citation	Study Setting	Type of Study	Topic	DSS Used	Conclusion
Folkens, 2009	Critical Care Unit	Sample Cases	DSS and Diagnostic Error	NeoPeDSS	DSS Improved Diagnosis
Graber & Matthew, 2008	Internal Medicine	Sample Cases	DSS and Diagnostic Error	Isabel	DSS Improved Diagnosis
Kostopoulou, Porat, Corrigan, Mamoud, & Dulaney, 2017	General Practice	Sample Cases	DSS and Diagnostic Error	Prototype DSS	DSS Improved Diagnosis
Martinez-Franco et al., 2018	General Medicine	Sample Cases	DSS and Diagnostic Error	DXplain	DSS Improved Diagnosis
Riches et al., 2016	n/a	Systematic Review	DSS and Diagnostic Error	n/a	DSS Improved Diagnosis
Shimizu, Nemoto, & Tokuda, 2018	Out-Patient Care	Live Setting	DSS and Diagnostic Error	UpToDate	DSS Improved Diagnosis
Phua, See, Khalizah, Low, & Lim, 2012	Critical Care Unit	Live Setting	DSS to answer clinical questions	UpToDate	DSS useful as a diagnostic aid
Berner, Maisiak, Heudebert, & Young, 2003	Internal Medicine	Sample Cases	Testing DSS for existence of diagnosis	Quick Medical Reference	DSS Improved Diagnosis
Graber & VanScoy, 2003	Emergency Department	Live Setting	Testing DSS for existence of diagnosis	QMR and Iliad	DSS results contained physicians initial diagnosis
Bavdekar & Pawar, 2005	Pediatric Critical Care Unit	Sample Cases	Testing DSS for existence of diagnosis	Isabel	DSS contained diagnosis when it was an initial option for physician the majority of the time
Medow, Arkes, & Shaffer, 2010	Critical Care Unit	Sample Cases	Using DSS for admittance decisions	PORT Score & CURB-65	DSS changed admittance decisions
Arancibia et al., 2019	Emergency Department	Live Setting	Using DSS for triage and admittance	Mediktor	DSS could speed up emergency room process

APPENDIX B

IAM QUESTION MODIFICATIONS AND CATEGORIZATION OF DIAGNOSTIC ERROR

Q indicates question and A indicates answer. For example Q4 refers to IAM Question 4 and A4a indicates Answer a to Question 4. A4b would be Answer b to Question 4.

Assessment Area	IAM Question and Answer Number	IAM Questions and Answers	IAM Questions and Answer Changes	Diagnostic Error
Information Use	Q4	Did you (will you) use this information for a specific patient? Yes/No/Possibly If Yes: Check all that Apply	Did you (will you) use this information to diagnose a specific patient? Yes/No/Possibly If Yes: Check all that Apply	N/A
Information Use	A4a	As a result of this information I managed (or will manage) this patient differently	As a result of this information I managed (or will manage) this patient diagnosis differently	No diagnostic error (this just assumes changed treatment)
Information Use	A4b	I had several options for this patient, and I used (will use) this information to justify a choice	I had several diagnoses for this patient, and I used (will use) this information to justify a choice	Diagnostic error without use of DSS
Information Use	A4c	I did not know what to do, and I used (will use) this information to manage this patient	I did not have a diagnosis, and I used (will use) this information to diagnose this patient	Diagnostic error without use of DSS
Information Use	A4d	I thought I knew what to do, and I used this information to be more certain about the management of this patient	I thought I knew the diagnosis, and I used this information to be more certain about the diagnosis.	No diagnostic error (confirmed diagnosis)
Information Use	A4e	I used this information to better understand a particular issue related to this patient	I used this information to better understand a particular issue related to this diagnosis	No diagnostic error (just increased understanding of the current diagnosis)
Information Use	A4f	I used (will use) this information in a discussion with this patient, or with other health professionals about this patient	I used (will use) this information in a discussion with this patient, or with other health professionals about the diagnosis	No diagnostic error (used information to help guide discussion)
Information Use	A4g	I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change for this patient	I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change in diagnosis for this patient	Diagnostic error without use of DSS
Patient Health Outcomes	Q5	For this patient, did you observe (or do you expect) any health benefits as a result of applying this information? Yes/No/Possibly If Yes: Check all that Apply	No change	N/A
Patient Health Outcomes	A5a	This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors)	No change	No diagnostic error

Assessment Area	IAM Question and Answer Number	IAM Questions and Answers	IAM Questions and Answer Changes	Diagnostic Error
Patient Health Outcomes	A5b	This information helped to prevent (will help to prevent) a disease or worsening of disease for his patient	No change	Diagnostic error without use of DSS
Patient Health Outcomes	A5c	This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient.	No change	Diagnostic error without use of DSS
Patient Health Outcomes	A5d	This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention	No change	No diagnostic error
Patient Health Outcomes	A5e	This information helped to increase this patient's knowledge, or their family or home health aides' knowledge	No change	No diagnostic error

APPENDIX C

QUALTRICS SURVEYS

Qualtrics Survey 1

Improving Diagnosis Survey

1. How long have you practiced medicine? ________
2. What are your medical credentials?
    a. MD
    b. DO
    c. PA
    d. Resident
    e. Nurse
    f. Other ___________
3. Do you have a critical care specialty? Ys/No If so what is it? ____________________
4. Which hospital System are you affiliated with? ________________
5. How often do you use a Decision Support System (DSS) to assist with diagnosis?
    a. Daily **(Skip to Q7)**
    b. Weekly **(Skip to Q7)**
    c. Monthly **(Skip to Q7)**
    d. Yearly **(Skip to Q7)**
    e. I have never used a DSS for diagnosis, but I have used a DSS for other purposes **(Skip to Q7)**
    f. I have never used a DSS **(Go to Q6)**

Path A – Physicians who have not used a DSS

6. If you have never used a decision support system (DSS), please explain why? _________ **(Skip to Q20)**

Path B – Physicians who have used a DSS

7. The last time you used a decision support system (DSS), which DSS did you use?
    a. DXplain
    b. UpToDate

c. Dynamed

d. Isabel

e. Other ________

8. Were you required to use a DSS? Yes/No
9. The last time you used a decision support system, was the use part of your diagnostic process/strategy? Yes/No
10. Was the use of the decision support system for a critically ill patient or a patient in a critical/intensive care unit? Yes/No

Start of IAM Questions

11. The last time you used a decision support system, why did you do this search for information?
    a. To address a clinical question (problem) about a specific patient
    b. To fulfil a personal educational objective
    c. To satisfy curiosity or for personal interest
    d. To look up something I had forgotten
    e. To share information with a patient, their family, or home health aides
    f. To exchange information with other health professionals
12. Did you find relevant information that partially or completely met your objective(s)? Yes/No
13. What is the impact of this information on you or your practice? (Check all that apply)
    a. My practice was (will be) changed and improved
    b. I learned something new
    c. This information confirmed I did (am doing) the right thing
    d. I am reassured
    e. I am reminded of something I already knew
    f. I am dissatisfied
    g. There is a problem with the presentation of this information
    h. I disagree with the content of this information

i. This information is potentially harmful

(If Answered E to Q5 go to Q14; Otherwise Skip to Q16)

Path C – Physicians who have used a DSS, but not as part of diagnosis (Last 2 IAM Questions)

14. Did you (will you) use this information for a specific patient? Yes/No/Possibly If Yes: Check all that Apply
    a. As a result of this information I managed (or will manage) this patient differently
    b. I had several options for this patient, and I used (will use) this information to justify a choice
    c. I did not know what to do, and I used (will use) this information to manage this patient.
    d. I thought I knew what to do, and I used this information to be more certain about the management of this patient
    e. I used this information to better understand a particular issue related to this patient
    f. I used (will use) this information in a discussion with this patient, or with other health professionals about this patient
    g. I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change for this patient.
15. For this patient, did you observe (or do you expect) any health benefits as a result of applying this information? Yes/No/Possibly If Yes: Check all that Apply
    a. This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors) **(Skip to Q20)**
    b. This information helped to prevent (will help to prevent) a disease or worsening of disease for his patient. **(Skip to Q20)**
    c. This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient. **(Go to Q16)**
    d. This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention **(Skip to Q20)**

e. This information helped to increase this patient's knowledge, or their family or home health aides' knowledge **(Skip to Q20)**

Path D – Physicians who have used a DSS as part of diagnosis (Last 2 IAM Questions

edited)

16. Did you (will you) use this information to diagnose a specific patient? Yes/No/Possibly If Yes: Check all that Apply
    a. As a result of this information I managed (or will manage) this patient diagnosis differently
    b. I had several diagnoses for this patient, and I used (will use) this information to justify a choice **(After Q17 Skip to Q19)**
    c. I did not have a diagnosis, and I used (will use) this information to diagnose this patient I used this information in a discussion with this patient, or with other health professionals about this patient **(After Q17 Skip to Q19)**
    d. I thought I knew the diagnosis, and I used this information to be more certain about the diagnosis.
    e. I used this information to better understand a particular issue related to this diagnosis
    f. I used (will use) this information in a discussion with this patient, or with other health professionals about the diagnosis
    g. I used (will use) this information to persuade this patient, or to persuade other health professionals to make a change in diagnosis for this patient **(After Q17 Skip to Q19)**
17. For this patient, did you observe (or do you expect) any health benefits as a result of applying this information? Yes/No/Possibly If Yes: Check all that Apply
    a. This information helped to improve (will help to improve) this patient's health status, functioning or resilience (i.e., ability to adapt to significant life stressors)
    b. This information helped to prevent (will help to prevent) a disease or worsening of disease for his patient.
    c. This information helped to avoid (will help to avoid) unnecessary or inappropriate treatment, diagnostic procedures, preventative interventions or a referral, for this patient. **(Skip to Q19)**

d. This information helped to decrease this patient's worries about a treatment, diagnostic procedure or preventative intervention

e. This information helped to increase this patient's knowledge, or their family or home health aides' knowledge

18. Was a follow-up conducted with the patient after diagnosis? Yes/No/Possibly If Yes: Was the diagnosis correct why/why not? ________________ **(Skip to Q20)**

Path E – Physicians who changed their diagnosis based on DSS information

19. Had you not changed your original diagnosis, what type of harm (if any) could it have caused to the patient? _____________________

Final Question for all survey participants

20. Do you think the use of decision support systems as a diagnostic aid will lower the rate of misdiagnosis? Yes/No Why or Why not?_____________________________________

If you would like to be entered into a drawing for an Amazon gif card please list your name and contact information below in survey number 2.

Qualtrics Survey 2

Drawing for Amazon Gift Card

Name: _____________________

Phone#: ____________________

Email Address: _______________

Preferred Contact: __Phone ___Email

APPENDIX D

SCRIPT TO ACCESS OKLAHOMA STATE MEDICAL BOARD WEBSITE

All code was written by Billyjack Levi Drain on 4/28/2016.

```
using System;
using System.Collections.Generic;
using System.IO;
using System.Linq;
using System.Net;
using System.Text;
using System.Text.RegularExpressions;
using System.Windows.Forms;

namespace Doctors
{
   static class Program
   {
      static string GetPage(int page)
      {
         var searchForm = WebRequest.Create("http://www.okmedicalboard.org/search");
         searchForm.Credentials = CredentialCache.DefaultCredentials;
         searchForm.Method = "POST";
         searchForm.ContentType = "application/x-www-form-urlencoded";

         var postData =
"licensenbr=&lictype=MD&lname=&fname=&practcounty=&status=&discipline=&hosp_county
=&hosp_code=&accepting_patients=&accepting_medicaid=&accepting_medicare=&language=
&licensedat_range=&order=lname&show_names=Show+Names+Only&specialty%5B%5D=CCA
&specialty%5B%5D=CCM&specialty%5B%5D=OCC&specialty%5B%5D=NCC&specialty%5B%5D=
CCP&specialty%5B%5D=PCC&specialty%5B%5D=CCS";
         if (page > 1)
            postData += $"&current_page={page-1}&next_page=Next+%3E%3E";

         var byteArray = Encoding.UTF8.GetBytes(postData);
         searchForm.ContentLength = byteArray.Length;

         using (var stream = searchForm.GetRequestStream())
         {
            stream.Write(byteArray, 0, byteArray.Length);
         }

         var response = searchForm.GetResponse();
         using (var textreader = new StreamReader(response.GetResponseStream()))
         {
            return textreader.ReadToEnd();
         }
      }
```

```
static string DoctorPage(string url)
{
   var searchForm = WebRequest.Create($"http://www.okmedicalboard.org{url}");
   searchForm.Credentials = CredentialCache.DefaultCredentials;
   searchForm.Method = "GET";

   using (var response = searchForm.GetResponse())
   {
      using (var reader = new StreamReader(response.GetResponseStream()))
      {
         return reader.ReadToEnd();
      }
   }
}

static void SeekToText(this TextReader reader, string text)
{
   var line = "";
   while (line?.Contains(text) == false)
   {
      line = reader.ReadLine();
   }
}

static string BuildUpTagTo(this TextReader reader, string text)
{
   var line = "";
   var result = "";
   while (line?.Contains(text) == false)
   {
      result += " " + line?.Trim();
      line = reader.ReadLine();
   }
   result = result.StripTags();
   while (result.Contains("  "))
      result = result.Replace("  ", " ");

   return result.StripTags();
}

static string StripTags(this string text)
{
   return Regex.Replace(text, "<.*?>", string.Empty);
```

```
        }

        [STAThread]
        static void Main(string[] args)
        {
            var pages = new List<string>();
            for (int i = 0; i < 9; i++)
            {
                pages.Add(GetPage(i + 1));
            }

            var rgx = new Regex(@"/licensee/MD/[0-9]+", RegexOptions.IgnoreCase);
            var links = pages.SelectMany(x => rgx.Matches(x).OfType<Match>().Select(m =>
m.Value)).ToList();

            var docPages = links.Select(DoctorPage);

            var doctors = new List<string>();
            foreach (var doc in docPages)
            {
                using (var reader = new StringReader(doc))
                {
                    reader.SeekToText("<table class=\"licensee-info\">");
                    reader.SeekToText("<th ");

                    var name = reader.ReadLine()?.StripTags()?.Trim();

                    // find the practice address
                    reader.SeekToText("Practice Address:");
                    reader.SeekToText("<td ");

                    // build up the address
                    var address = reader.BuildUpTagTo("/tr>");

                    // build the phone number
                    reader.SeekToText("Phone #:");

                    var phone = reader.BuildUpTagTo("/tr>");

                    reader.SeekToText("Fax #:");
                    var fax = reader.BuildUpTagTo("/tr>");

                    reader.SeekToText("County:");
                    var county = reader.BuildUpTagTo("/tr>");
```

```
reader.SeekToText("License:");
var license = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Dated:");
var dated = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Expires:");
var expires = reader.BuildUpTagTo("/tr>");

reader.SeekToText("License Type:");
var licenseType = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Specialty:");
var specialty = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Status:");
var status = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Status Class:");
var statusClass = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Restricted to:");
var registrictedTo = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Registered to Dispense:");
var registeredToDispense = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Certifications:");
var certifications = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Medical School:");
var medicalSchool = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Graduated:");
var graduated = reader.BuildUpTagTo("/tr>");

reader.SeekToText("CME Year:");
var CMEYear = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Disciplinary History:");
var disciplinaryHistory = reader.BuildUpTagTo("/tr>");

reader.SeekToText("Medicaid:");
```

```
                var medicaid = reader.BuildUpTagTo("/tr>");

                reader.SeekToText("Medicare:");
                var medicare = reader.BuildUpTagTo("/tr>");

                reader.SeekToText("HMO/PPO:");
                var hmoppo = reader.BuildUpTagTo("/tr>");


doctors.Add($"{name}\t{address}\t{phone}\t{fax}\t{county}\t{license}\t{dated}\t{expires}"
                        + $"\t{licenseType}\t{specialty}\t{status}\t{statusClass}\t{registrictedTo}"
                        + $"\t{registeredToDispense}\t{certifications}\t{medicalSchool}\t{graduated}"
                        + $"\t{CMEYear}\t{disciplinaryHistory}\t{medicaid}\t{medicare}\t{hmoppo}");
            }
        }

        using (var dialog = new SaveFileDialog())
        {
            if (dialog.ShowDialog() == DialogResult.OK)
            {
                using (var textWriter = new StreamWriter(dialog.OpenFile()))
                {

textWriter.Write("Name\tAddress\tPhone\tFax\tCounty\tLicense\tDated\tExpires\t");
                    textWriter.Write("License Type\tSpecialty\tStatus\tStatus Class\tRegistered
to\t");
                    textWriter.Write("Registered to dispense\tCertifications\tMedical
School\tGraduated\t");
                    textWriter.WriteLine("CME Year\tDisciplinary History\tMedicaid\tMedicare\tHMO
PPO");
                    foreach (var dr in doctors)
                        textWriter.WriteLine(dr);
                }
            }
        }
    }
  }
}
```

APPENDIX E

CODE BOOK

- Rows highlighted in yellow indicate variables that were excluded from the study because all the data points were the same.
- Items coded as blank indicates the question was presented to the physicians and they left it blank.
- Missing data indicates the question was not presented to the physician due to the logic of the survey.

Survey Question	Variable	SPSS V Name	Values
	Respondent	ID	Number assigned to each survey
Q1	Years in Medicine	Time	0 = None
			1 = 1-10
			2 = 11-20
			3 = 21-30
			4 = 31-40
Q2	Medical Credentials	Education	0 = PA, Resident, Nurse, Other
			1 = MD, DO
Q3	Critical Care Specialty	Specialty	0 = None
			1 = Internal
			2 = Pediatrics
			3 = Pulmonary
			4 = Surgical
Q4	Hospital System	Hospital	0 = Blank
			1 = OU Medical
			2 = Children's Hospital
Q5	Frequency of DSS use	Frequency	0 = Never used (options e and f)
			1 = Yearly (option d)
			2 = Monthly (option c)
			3 = Weekly (option b)
			4 = Daily (option a)
Q6	Why don't use DSS	DSSNoUse	0 = Blank
			1 = Don't know what DSS is
			2 = Not available
Q7	DSS Used		
		DXplain	0 = No
			1 = Yes
			9 = Missing Data
		UpToDate	0 = No
			1 = Yes
			9 = Missing Data

Survey Question	Variable	SPSS V Name	Values
		Dynamed	0 = No
			1 = Yes
			9 = Missing Data
		Isabel	0 = No
			1 = Yes
			9 = Missing Data
		DSSOther	0 = No
			1 = Yes
			9 = Missing Data
Q8	Required to Use DSS	DSSRequire	0 = No
			1 = Yes
Q9	DSS Part of Diagnosis	DSSDiagnosis	0 = No
			1 = Yes
			9 = Missing Data
Q10	DSS Used for Critically Ill Patient	CCPatient	0 = No
			1 = Yes
			9 = Missing Data
	DSS Used for non critically ill patient	NonCCPatient	0 = No
			1 = Yes
			9 = Missing Data
Q11	Purpose of DSS Search		
	a. Address clinical questions	Purpose_Ques	0 = No / Missing Data
			1 = Yes
	b. fulfil personal objective	Purpose_Obj	0 = No / Missing Data
			1 = Yes
	c. Satisfy curiosity	Purpose_Curi	0 = No / Missing Data
			1 = Yes
	d. look up forgotten info	Purpose_Forgot	0 = No / Missing Data
			1 = Yes
	e. Share info with patient	Purpose_Patient	0 = No / Missing Data
			1 = Yes
	f. Exhange info with healthcare	Purpose_Health	0 = No / Missing Data
			1 = Yes
Q12	DSS info relevant/met objective	DSSRelevant	0 = No
			1 = Yes
			9 = Missing Data
Q13	Impact on Practice		
	a. Practice changed/improved	Impact_Improved	0 = No / Missing Data

Survey Question	Variable	SPSS V Name	Values
		1	1 = Yes
	b. Learned something new	Impact_Learned	0 = No / Missing Data
		2	1 = Yes
	c. Information confirmed actions	Impact_Confirm	0 = No / Missing Data
		4	1 = Yes
	d. I am reassured	Impact_Reassured	0 = No / Missing Data
		4	1 = Yes
	e. I am reminded of info already knew	Impact_Reminded	0 = No / Missing Data
		2	1 = Yes
	f. I am dissatisfied	Impact_Dissatisfied	0 = No / Missing Data
		0	1 = Yes
	g. Problem with DSS info	Impact_Problem	0 = No / Missing Data
		1	1 = Yes
	h. Disagree with DSS info	Impact_Disagree	0 = No / Missing Data
		0	1 = Yes
	I. Info potentially harmful	Impact_Harmful	0 = No / Missing Data
		0	1 = Yes
Q14	Use info for Specific Patient		
	a. Managed patient differently	Patient_Different	0 = No
			1 = Yes
	b. several options, justify choice	Patient_Justify	0 = No
			1 = Yes
	c. did not know, manage patient	Patient_Manage	0 = No
			1 = Yes
	d. Thought I knew, info more certain	Patient_Certain	0 = No
			1 = Yes
	e. Better understand patricular issue	Patient_Issue	0 = No
			1 = Yes
	f. Discussion with patient or health team	Patient_Discuss	0 = No
			1 = Yes
	g. Persuade to make change	Patient_Persuade	0 = No
			1 = Yes
Q15	Health Benefits for Patient		
	a. Improved patients health	Benefit_Improved	0 = No
			1 = Yes

Survey Question	Variable	SPSS V Name	Values
	b. prevent disease or worsening condition	Benefit_Prevent	0 = No
			1 = Yes
	c. avoid unecesary treatment/procedures	Benefit_Treastment	0 = No
			1 = Yes
	d. decrease patient worries	Benefit_Worry	0 = No
			1 = Yes
	e. incrase patients knowledge	Benefit_Knowledge	0 = No
			1 = Yes
Q16	Use info to diagnose Specific Patient		
	a. Managed patient diagnosis differently	Diagnose_Different	0 = No
			1 = Yes
			9 = Missing Data
	b. several diagnosis, justify choice	Diagnose_Justify	0 = No
			1 = Yes
			9 = Missing Data
	c. did not know diagnosis, diagnose patient	Diagnose_Manage	0 = No
			1 = Yes
			9 = Missing Data
	d. Thought I knew diagnosis, info more certain	Diagnose_Certain	0 = No
			1 = Yes
			9 = Missing Data
	e. Better understand patricular issue for diagnosis	Diagnose_Issue	0 = No
			1 = Yes
			9 = Missing Data
	f. Discussion with patient or health team	Diagnose_Discuss	0 = No
			1 = Yes
			9 = Missing Data
	g. Persuade to make change in diagnosis	Diagnose_Persuade	0 = No
			1 = Yes
			9 = Missing Data
Q17	Health Benefits for Patient with Diagnosis		
	a. Improved patients health	Benefit_Improved	0 = No

Survey Question	Variable	SPSS V Name	Values
			1 = Yes
			9 = Missing Data
	b. prevent disease or worsening condition	Benefit_Prevent	0 = No
			1 = Yes
			9 = Missing Data
	c. avoid unecesary treatment/procedures	Benefit_Treatment	0 = No
			1 = Yes
			9 = Missing Data
	d. decrease patient worries	Benefit_Worry	0 = No
			1 = Yes
			9 = Missing Data
	e. incrase patients knowledge	Benefit_Knowledge	0 = No
			1 = Yes
Q18	Follow-up Conducted	Follow_up	0 = No
			1 = Yes
	Why/why not follow-up		
Q19	If not changed Diagnosis, what harm caused	Harm	0 = Blank / no harm assumed
			1 = Other treatment Given / assumed harm cased
			9 = Missing Data
Q20	Will DSS use lower diagnostic error	ReduceError	0 = No / Missing Data
			1 = Yes
	Why/Why not was not coded, not enough to categorize		
Analysis	Based on answers, was a diagnostic error made	DiagnosticError	0 = No
			1 = Yes
			9 = Missing Data

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