NURSE PRACTITIONERS' USE OF ULTRASOUND TO DIAGNOSE KIDNEY STONES IN THE EMERGENCY DEPARTMENT

by

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As members of the DNP Project Committee, we certify that we have read the DNP Project prepared by Amanda Marie Schmidtmann entitled "Nurse Practitioners' Use of Ultrasound to Diagnose Kidney Stones in the Emergency Department" and recommend that it be accepted as fulfilling the DNP Project requirement for the Degree of Doctor of Nursing Practice.

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Final approval and acceptance of this DNP Project is contingent upon the candidate's submission of the final copies of the DNP Project to the Graduate College.

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DEDICATION

I would like to dedicate this paper to all the nurses that work in the emergency room that care for kidney stone patients, who constantly question the provider and wonder if CT is best practice for their patients.

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ABSTRACT

Background: Kidney stones are a common, painful disorder that can affect as many as one out of 11 people in the United States (Goldfarb & Arowojolu, 2013). The gold standard for diagnosing kidney stones is currently computed tomography (CT). However, because CT scans emit radiation during the exam, they may cause more harm than good. According to recent research, ultrasound may be used to diagnose kidney stones with similar accuracy and reliability. Ultrasounds are also safer and more cost effective for patients and the healthcare system.

Purpose: The purpose of this project is to describe nurse practitioners (NPs) use of ultrasound to diagnose kidney stones in the emergency department (ED). The information from this project was compared with the recent literature and used to develop an evidence-based practice recommendation for diagnosing suspected kidney stones in the ED.

Methods: A 15-item survey was mailed to emergency department NPs across the United States (U.S.). Descriptive statistics were used to analyze the quantitative results. One open-ended question was also posed, and findings were grouped by commonalities of clinical experiences.

Results: Analysis of survey responses indicate that all of the respondents use CT scan to diagnose kidney stones. However, the majority of the respondents also feel that ultrasound could be used in the ED to diagnose kidney stones. The results also demonstrate that even though there is no nationally or internationally accepted standardized guideline for diagnosing kidney stones in the ED, many EDs across the country are instituting their own protocols.

INTRODUCTION

Kidney stones have been described as one of the most painful health disorders a human can experience. The onset of pain is often so abrupt and so acute that it can bring a grown man to tears. Kidney stones can cause days of pain and suffering, which can lead to missed work, and lost wages. Furthermore, kidney stone disease can cause complications such as urinary tract infections, electrolyte imbalances, and acute renal failure. Left untreated, these complications may lead to prolonged hospitalizations, which can cause financial concerns to the patient and to the healthcare system.

Kidney stones frequently cause multiple signs and symptoms of distress. Commonly, kidney stone pain presents as severe intermittent flank pain that can radiate to the lower abdomen, groin, or genitalia as the stone or stones make their way through the urinary system (Carter & Green, 2011). Nausea, vomiting, dysuria, and hematuria are among the unpleasant accompanying symptoms that can occur (Carter & Green, 2011).

Often the pain of a kidney stone, and other associated symptoms, are so intense and troublesome that patients seek care in the emergency department (ED). Frequently, the initial diagnosis of acute renal calculi or kidney stones is made while the patient is under the care of the ED team when the diagnosis of acute kidney stones is actually made. Currently, computed tomography (CT) is the preferred method for evaluation and diagnosis of kidney stones due to its accuracy, availability, and rapid results, even though CT imaging emits high doses of radiation (Ray, Ghiculete, Pace, & Honey, 2010; Moore & Scoutt, 2012).

The diagnosis of kidney stones may have significant consequences on patient morbidity, lost wages, and healthcare expenses (Carter & Green, 2011). Over 3.4 million kidney stone encounters are recorded per year with an estimated $139 million in lost wages, and a $1.83 billion cost to healthcare in the United States (U.S.) (Carter & Green, 2011; Clark, Thompson, & Optenberg, 1995; Moore & Scoutt, 2012; Kirpalani, Khalili, Lee, & Halder, 2005). The elevated healthcare costs may be related to current utilized diagnostics.

Kidney stones are also known to be recurrent. In fact, 50% of people afflicted with kidney stones will have a recurrence (Horner, Einstein, & Herts, 2005). Due to the recurrent nature of kidney stones, repetitive CT scans may not be in the best interest of the patient or the healthcare system.

While CT is the preferred method of diagnosing kidney stones, and is quick, accurate and efficient, some attributes of CT can be causing more harm than good. Those patients that present with recurrent kidney stones may be receiving more CT scans to diagnose the same disorder. CT emits high doses of radiation, and is costly to patients. While it is the most common and frequently preferred means to diagnose kidney stones, it is possible that an alternative, less costly and less risky means could exist.

As previously stated, CT provides a highly reliable means to diagnose the size and location of kidney stones. For this reason, some providers may prefer to order CT rather than consider an alternate diagnostic tool. However, patients who recurrently form kidney stones may be able to provide a more specific history of present illness, enabling the health care team to rely on a less harmful imaging modality such as ultrasound as an option for diagnosis. The purpose of this paper is to describe nurse practitioners' (NPs) use of ultrasound to diagnose kidney stones in the emergency department (ED). The results from this project were compared with the literature and then used to develop evidence-based practice recommendations for diagnosing suspected urolithiasis in the ED.

Background

In general, kidney stones occur more frequently in middle-aged males. Kidney stones typically occur in individuals between the ages of 20-60 years old; the lifetime prevalence among males is 10-12% and 5-6% in women (Dawson & Tomson, 2012; Edvardsson, Indridason, Haraldsson, Kjartansson, & Palsson, 2012). However, in the sixth decade of life, kidney stone incidence decreases in men and increases in women (Moe, 2006). Kidney stone formation is most prevalent among Caucasians, followed by Hispanics, Asians, and then Africans (Carter & Green, 2011). Approximately 130 people per 100,000 will develop a stone each year and 75% of those will develop a recurrent stone within 5-10 years (Turk, Knoll, Petrik, Sarica, Seitz, & Straub, 2011; Dawson & Tomson, 2012). With each recurrence, the risk increases and the time between stone formation decreases (Moe, 2006).

Geographical location and career appear to play a role in kidney stone production. For example, kidney stones are more likely to afflict people who reside in hot climates. Sun exposure, dehydration, and synthesis of vitamin D can increase the likelihood of stone production (Moe, 2006). Those who work in conditions that can cause dehydration such as construction workers, fire fighters, and farmers or those who have careers that can delay the ability to urinate when needed such as nurses, pilots, and long-distance truck drivers are at increased risk for kidney stones (Goldfarb & Arowojolu, 2013).

Some chronic diseases may be associated with increased risk for kidney stone formation. These include hyperparathyroidism, gastrointestinal disorders or malabsorptive conditions, sarcoidosis, and lacking one kidney (Turk, Knoll, Petrik, Sarica, Seitz, & Straub, 2011). Those patients that have a solitary kidney have an inferior filtration rate and can build up more materials that can cause stones.

Dietary influences have been noted among those at risk for kidney stones. Diets high in salt, low in calcium, low in potassium, and high in animal proteins are susceptible to stone production (Dawson & Tomson, 2012). Those who have low fluid intake and higher than normal mineral intake, such as post-menopausal women, who take vitamin D supplements, are at higher risk of developing a kidney stone.

Genetic factors may contribute to kidney stone formation. Genetic causes are attributed to traits that have both environmental, such as climate and diet, and hereditary or inherited determinants. Hypercalciuria, or high calcium development in the urine, has the same genetic predisposal as obesity, hypertension, and diabetes (Moe, 2006). Furthermore, at least 50% of individuals diagnosed with kidney stones have a genetic predisposition or a first line relative who has also been diagnosed with kidney stones (Moe, 2006).

Certain medications may raise the risk of kidney stones. For example, medications that cause diuresis such as thiazide diuretics can contribute to the formation of kidney stones (Carter & Green, 2011). Diuretics can dehydrate the patient by allowing the urinary system to expel fluids, but then may leave behind electrolytes and other materials that can build up and cause kidney stones.

Diagnosis

CT scan is considered the preferred imaging modality for kidney stone imaging as it is deemed accurate and widely available. Furthermore, evidence shows that CT is highly effective at diagnosing urolithiasis with 99% accuracy (Sandhu, Anson, & Patel, 2003). CT scans are commonly found in most hospitals in the U.S. and can take less than 10 minutes to scan the patient. However, CT scans are not without risk, and repeated CT scans may significantly raise the risk of cancers caused by radiation. The clinical decision tree for suspected kidney stones should include the cost factor, radiation exposure and emission, and a risk to benefit analysis.

Currently, there are no published clinical guidelines for diagnosing kidney stones in the ED in the United States. Brown (2006) suggests a guideline may be applicable for rationality and cost effectiveness due to the volume of patients evaluated every year. Hymas, Korley, Pham and Matlaga (2011) recommend a guideline as an opportunity to improve practice patterns by choosing alternate imaging. Danziel and Noble (2013) contend there is currently enough evidence for an algorithm for kidney stone management; and a diagnostic imaging strategy could improve patient care by reducing unnecessary imaging, healthcare costs, and radiation doses to patients. Broder, Bowden, Lohr, Babcock and Yoon (2007) propose that a clinical decision rule for CT use in suspected urolithiasis could reduce radiation exposures without harming patients and their care. Lastly, Goldstone and Bushnell (2008) state clinicians should be aware of the risks and benefits of repeat imaging of patients with urolithiasis, and a rule should be developed regarding repeat imaging on such patients.

While it is fairly well documented that a guideline may be necessary, it is difficult to ascertain current imaging modality usage by advanced practice nurses working in the ED in the U.S. Facilities across the country have varied equipment available, and practitioners have varied protocols to follow, whether self-imposed or facility/management guided.

Significance of the Problem

Many people who suffer from kidney stones are first seen in the ED due to the extreme pain and associated symptoms. Most of those will undergo a CT scan. While reliable, CT scans may contribute to higher health care costs and to more healthcare concerns for patients. There is evidence that ultrasound, which is associated with less cost and less risk over time, may be useful for diagnosing kidney stones.

As nurse practitioners undertake more roles and responsibilities within the healthcare community, knowledge of safe and cost-effective diagnostics for recurrent disorders such as kidney stones is essential. A good patient history may contribute to the diagnosis of kidney stones, especially in patients who are experiencing a recurrence. Patient history may even enable NPs to rely less on CT and consider diagnostics such as ultrasound, which is significantly less harmful and more cost-effective.

Purpose and Aims

The purpose of this project is to describe NPs use of ultrasound to diagnose kidney stones in the ED. The results of a 15-item survey administered to NPs working in ED was compared with the recent literature and used to develop an evidence-based practice recommendation for diagnosing suspected kidney stones in the ED. Specific aims included: describing current diagnosing modalities among NPs working in the ED; comparing findings with extant literature; and developing a best practice recommendation for diagnosis of kidney stones.

PDSA Model for Quality Improvement

The Plan-Do-Study-Act (PDSA) model for quality improvement was the framework used to develop a best practice recommendation for diagnosis of kidney stones in the ED. The

Institute for Healthcare Improvement developed the PDSA cycle as a tool for simplifying and measuring the success of a quality improvement project (Agency for Healthcare Research and Quality [AHRQ], 2013; Varkey et al., 2007). There are three questions from this tool that should be acknowledged:

1. What is to be accomplished?
2. What changes can be made to ensure it is accomplished?
3. What will indicate that the changes made led to the accomplished task? (Dover, 2012)

The four phases of the PDSA cycle resemble the scientific experimental method: formulating a hypothesis, collecting data, analyzing the data and the results, and refining the hypothesis based on the data collected, which makes the PDSA cycle the most appropriate quality improvement framework for healthcare providers (Taylor, McNicholas, Nicolay, Darzi, Bell, & Reed, 2014).

Literature Review

The objective of this literature review was to critically analyze current available literature of urolithiasis diagnostic methods across the U.S. and other developed countries to determine the best modalities for a best practice recommendation. The information from this literature review was used to develop a survey for nurse practitioners to determine current modality usage and barriers to using other methods. The data gathered from the surveys was used to facilitate the development of a best practice recommendation for urolithiasis diagnosis in the ED.

Literature Review Method

Available articles were obtained via a systematic review executed in the electronic database of PubMed with a MESH search for kidney stones. “Kidney stones” was later corrected to kidney calculi. When a search is executed in the MESH form of PubMed, it concurrently searches CINAHL, MD Consult, and Google Scholar. The “AND diagnosis” was added to the MESH search bar, and articles were filtered for classic articles, clinical trial, comparative study, controlled clinical trial, evaluation studies, guideline, journal article, meta-analysis, multicenter study, practice guideline, randomized controlled trial, review, systematic reviews, and validation studies, as well as publication date within the last 10 years, humans, and English language. This search generated 1644 articles.

A second PubMed MESH search was executed for renal calculi with the box checked for diagnosis, including all the aforementioned filters, which produced 425 articles. The titles and abstracts of the 425 articles were skimmed and funneled down to 54 that were transferred into a RefWorks account, and eventually, further funneled down to 45 articles. Twenty-five articles were deemed useful as they contained information regarding imaging modalities for urolithiasis in the ED, trends in imaging modalities among ED providers, general information about kidney stones and imaging, and information about CT scan overuse among ED providers. NCBI was set to alert the researcher for new articles via email; 52 articles were used from the RefWorks library.

An electronic search of MD Consult was conducted with the terms “guidelines and kidney stones and diagnosis” which produced 538 articles; 230 articles were refined from the 538 when filtered for full text articles. Many of the articles were duplicates of the PubMed MESH search results, save five, which were transferred into RefWorks. A Google Scholar search was also performed including “kidney stones and diagnosis and emergency and imaging” through years 2005-2013 that produced over 15,000 articles. Several pages of articles listed were perused and seven articles chosen and transferred. Finally, *Science Direct* suggests articles when one is chosen to view, and eight articles were chosen from that site. A total of 72 articles were considered, 41 were chosen.

The articles were reviewed and analyzed for imaging modalities, other diagnostic methods, safety issues, cost of imaging, and best practice recommendations for potential use in guideline development.

Physiology of Kidney Stone Formation

Kidney stones are thought to be formed by low fluid intake and low fluid output that can cause an accumulation of the materials that composes urine. Urine is composed of organic and inorganic substances, salts, and several other compounds including calcium, phosphate, oxalate, and uric acid (Carter & Green, 2011; Moe, 2006). When urine becomes supersaturated with these stone-forming compounds, kidney stones are formed out of the salt crystals that accumulate together (Carter & Green, 2011; Moe, 2006). While there are molecules that can serve to inhibit crystal formation by decreasing crystal growth and aggregation, the lack of these molecules is what creates a favorable environment for crystal formation (Carter & Green, 2011). The exact mechanism of the crystal accumulation is still unknown, but it can be thought of as a multifactorial process that encompasses a high concentration stone-forming salts and a low amount of inhibitory proteins (Carter & Green, 2011).

Kidney Stone Composition

Kidney stones are comprised of different materials depending on what has caused the stones formation. There are three major types of kidney stones: calcium, which can be oxalate or phosphate, struvite, and uric acid. Calcium stones comprise about 75% of all stones, while struvite composes 15% and uric acid 6% (Carter & Green, 2011). Other stones include cystine stones, which are formed in those patients that have an inherited disorder that affects renal transport and causes cystinuria, and medication derived stones such as indinavir and triamterene stones (Dawson & Tomson, 2012; Moe, 2006; Sandhu, Anson, & Patel, 2003).

The type of stone that is formed is contingent on the patient's hydration status, certain disorders and/or mechanisms, and idiopathic causes. Calcium stones are the most common and are called calcareous or containing calcium (Carter & Green, 2011). All other compositions of stones are considered non-calcareous. Calcium stones are formed when a patient is in a hypercalcemia or excessive calcium type of state, which can increase the saturation of calcium salts in the urine; this can include patients with hyperparathyroidism, absorptive hypercalciuria via the gut, or immobilization due to bone resorption, myeloproliferative disorders, enzymatic defects, inherited renal dysfunction, and diets high in salt and protein (Moe, 2006).

Struvite and uric acid stones are less common than calcium but are formed due to disorders that are more common. Struvite or infection stones require a compound of alkaline urine and ammonia, which is believed to be produced by splitting bacterial organisms (Carter & Green, 2011; Moe, 2006). The patients that develop struvite stones are frequently those with recurrent urinary tract infections; therefore, women and patients with anatomic abnormalities are at risk (Carter & Green, 2011; Moe, 2006). Uric acid stones are mostly influenced by low urine pH, but hyperuricosuria or high levels of uric acid in the urine is also a factor (Carter & Green, 2011). Patients at risk include those who may have acid-base imbalances including obese patients, diabetics, hypertensive patients, and those taking thiazide diuretics (Green & Carter, 2011; Moe, 2006). Stone composition is an important factor when deciding on which imaging modality to choose because not all stones can be visualized with any method.

Stone Visualization

As discussed earlier, kidney stones are comprised of differing materials based on what bodily mechanism has caused the formation, but not all stones are created equal in the way they are visualized upon imaging. Kidney stones can be radiopaque or radiolucent. Calcareous stones are considered radiopaque and can be visualized as white on plain radiographs such as an x-ray (Carter & Green, 2011). Non-calcareous stones are considered radiolucent and are poorly visualized with plain radiograph as grey or black in color (Carter & Green, 2011). The importance of stone visualization is evident when deciding on which imaging modality to use.

Imaging Modalities

Acute kidney stones can present like many other disease processes. Imaging became important for several reasons: confirmation of the diagnosis, to rule out other pathologies that might require further intervention, determination of the size and position of the stones, which is significant for management, and to exclude obstruction, which is important for treatment (Moore & Scoutt, 2012).

When discussing kidney stone formation, it is important to understand the concepts of sensitivity and specificity. Sensitivity is defined as the number of people with a positive exam for a specific disorder divided by the people already diagnosed with the disorder; an exam with a high sensitivity will not give a false measure of the people with the disorder (Bonis, 2014). Specificity is the number of people with a negative exam who do not have the disorder divided by the number of people who do not have the disorder; an exam with a high specificity will rarely identify people as having as disorder that they do not have (Bonis, 2014). The next section will describe current imaging modalities and methods for suspected kidney stones.

Intravenous Urogram

Prior to 1995, and the emergence of CT scan as the preferred method for kidney stone evaluation, intravenous urography or urogram (IVU), was considered the most reliable means of detection, with a sensitivity of 64% and a specificity of 92% (Ulusan, Koc, & Tokmak, 2007; Horner, Einstein, & Herts, 2005). An IVU is a radiograph that allows visualization of the urinary system after the installation of contrast material through a peripheral intravenous site. The contrast moves through the kidneys, ureters, and bladder while the radiograph takes short interval pictures; an obstruction is identified with a delay in contrast movement through the system (John Hopkins Medicine, n.d.).

IVU was ultimately replaced as the preferred diagnostic imaging modality due to use of intravenous contrast, which is a relative contraindication in individuals with a previous reaction to contrast and for those with renal insufficiency, as well as due to time constraints. An IVU can typically take anywhere from 45-60 minutes or longer if there is obstruction (Horner, et al, 2005). IVU is also poor at visualizing radiolucent stones, and may actually diagnose the stone as a tumor (Heidenreich, Desgrandchamps, & Terrier, 2002). Typically, IVU emits 2.5 times more radiation then a chest radiograph (Sebastian & Tait, 2011).

Plain Radiograph

Plain radiography or KUB (kidney-ureter-bladder) uses invisible electromagnetic energy beams to show visualizations of bones, organs and internal structures onto film or digital media and, historically, was the preferred imaging choice with a sensitivity of 44-77% and a specificity of 80-87% (John Hopkins Medicine, n.d; Heidenreich et al., 2002). However, between 25-30% of stones are not radiopaque (Carter & Green, 2011). While KUB emits less radiation than an

IVU, it is still considered unsafe for certain populations, such as pregnant women.

Ultrasound

Recurrent stone formers, women of childbearing age or pregnant women should be considered for alternate imaging modalities such as ultrasound. Ultrasound has an advantage over plain films and IVU, as it is easily accessible, able to be used at the bedside in the emergency department, and is relatively inexpensive (Ulusan et al., 2007). Sensitivity is in the range of 29-81%, which is dependent on stone size, location, skill of the ultrasonographer, and patient body habitus (Lipkin & Preminger, 2013). Sensitivity is at its highest when secondary signs of kidney stones are being considered including hydronephrosis and urinary tract structure dilations (Heidenreich et al., 2002). Ultrasound specificity is high at 82-90% (Lipkin & Preminger, 2013). In a small study that evaluated the usefulness of ultrasound in patients suspected of having a kidney stone, sensitivity was 98% and specificity was 100% (Carter & Green, 2011).

An ultrasound is performed with a handheld probe or transducer that sends out ultrasonic sound waves that bounce off the organ like an echo and return to the transducer, which picks up the wave and develops a picture of the organ (John Hopkins Medicine, n.d.). Ultrasonography uses a water-based gel that is spread on the skin to allow the transducer to pick up the echo (John Hopkins Medicine, n.d.). Depending on the ultrasonographer, this procedure can take 30 minutes.

While CT is typically employed for diagnosing kidney stones, those patients who are recurrent stone formers should be considered for a less harmful, less expensive modality. The average cost of an ultrasound in the state of Arizona, before insurance coverage, of the abdomen is <$400, and ultrasound does not emit any radiation (Honor Health, 2015). The price of a diagnostic may not be a large factor when the practitioner is faced with an acute illness, but a recurrent illness should be acknowledged differently.

Other than cost, stone size is a concern when choosing an imaging modality for stone diagnosis. Ultrasound has been deemed unacceptable to diagnose stones by some due to its inability to locate stones less than 3mm in size; however, stones smaller than 4mm commonly pass without any intervention (Horner et al., 2005). Further, ultrasound has a higher sensitivity for locating larger stones when compared to CT scan, and larger stones will definitely require intervention (Moak et al., 2012). Choosing the right diagnostic for stone size is an important consideration as patient safety is paramount, and intervention will be needed in those patients with stones too large to pass.

When considering patient safety, potential harm should be factored into decision-making as up to 20% of patients exceed yearly radiation dosage from CT scans (Hymas et al., 2011). Additionally, young females should always be considered for ultrasounds as an alternate modality since the radiation dose to females is significantly higher than it is for males; the lifetime risk of cancer from one abdominal CT is 1 in 500 in females and 1 in 1300 in males (Patatas, Panditaratne, Wah, Weston, & Irving, 2012).

Magnetic Resonance Imaging

Another diagnostic tool that emits no radiation and is useful in determining signs of obstruction and other pathologies is Magnetic Resonance Imaging (MRI). MRI uses a combination of radiofrequencies, magnets, and a computer to visualize images of structures in the body (John Hopkins Medicine, n.d.). An MRI creates a magnetic field that arranges hydrogen atoms in the body; the radio wave pulses from the scanner that rearranges the atoms, and while the atoms are re-aligning, the nuclei sends out radio signals that are received by the computer, which develops an image on a computer monitor (John Hopkins Medicine, n.d.). While MRI cannot directly visualize stones, it still maintains a sensitivity of 93% and a specificity of 95% (Lipkin & Preminger, 2013). Furthermore, an MRI would be the safest option for women of childbearing age and recurrent stone formers, as it emits no radiation. However, it is used infrequently due to cost and the time it takes to scan; it is also contingent on the individual's ability to remain still, can induce claustrophobia, and is not readily available to many facilities (Sebastian & Tait, 2011).

Computed Tomography

The "gold standard" for diagnostic imaging for urolithiasis is generally accepted as CT scan, and is the benchmark to which all other imaging modalities are compared to when deciding whether to utilize another option. CT scan is a combination of x-ray and computer technology that produces "slices" or horizontal or axial images by moving the beam of x-ray energy in circles around the body, which allows for different views of the organ; the information is then sent to a computer that depicts the data on a computer monitor (www.hopkinsmedicine.org, n.d.). A CT can be done with or without contrast, but is commonly used without contrast to visualize kidney stones.

Non-contrast computed tomography (CT) is considered the most reliable means of evaluation due to its sensitivity of 95-98% and specificity of 96-98% (Lipkin & Preminger 2013). A CT is superior in assessing stone amount, size, and location, regardless of patient size, and is a quick procedure often taking less than 10 minutes (Ulusan et al., 2007; Horner et al., 2005). However, CT is expensive, emits 12 times the amount of radiation than a kidney-ureter-bladder x-ray, and in many facilities, is not readily available (Goldstone & Bushnell, 2008; Gaspari & Horst, 2005).

While low dose CT is an option with sensitivities and specificities being comparable to non-contrast CT, availability is still a disadvantage (Lipkin & Preminger, 2013). The newest option for stone diagnosis is non-contrast computed tomography (NCCT), which could become the new gold standard for urolithiasis evaluation due to its sensitivity of 95-98% and specificity of 96-98% (Lipkin & Preminger, 2013). CT, of any kind, can be considered superior in diagnosing kidney stones.

CT scans are considered health care technology; and health care technology may be associated with the increasing cost of health care for patients. While it is difficult to verify the cost of a CT scan due to many different insurance policies and facilities, an average cost in the state of Arizona, before insurance coverage, for a CT scan without contrast is >$600 (Honor Health, 2015). In 2008, 277 out of 606 patients that were being evaluated for flank pain received a CT scan; yet, in 2000, only 77 out of 434 received a CT scan making the increased use of CT scans statistically significant with a reported increase of 12/1,000 to 33/1,000 in seven years (Hymas et al., 2011). However, while there was an increase in CT scans reported, there was not an increase in kidney stones found or admissions for kidney stones (Moore & Scoutt, 2012).

Another source that echoes the aforementioned increase in CT scans without an increase in diagnosis is the National Hospital Ambulatory Medical Care Survey (NHAMCS). This document is an objective, reliable survey that is used to gather information about the use of ambulatory medical care in the U.S., and it showed that CT scans used to evaluate urolithiasis increased from 4% in 1996 to 42.5% in 2007 (Westphalen, Hsia, Maselli, Wang, & Gonzales, 2011). While CT scan usage increased, the proportion of individuals diagnosed with kidney stones did not increase, remaining at 19% (Westphalen et al., 2011). Further, individuals admitted to the hospital for kidney stones or other significant pathologies did not change significantly, increasing from 10% to 11% (Westphalen et al., 2011).

The use of CT scans can potentially be doing more harm than good. Medical imaging may be responsible for the greatest radiation exposure to the U.S. population with CT scans contributing too much higher doses of radiation than a standard x-ray (Shah, Slovis, Runde, Godbout, Newman, & Lee, 2013). Because kidney stones are often first diagnosed in young males with a high recurrence rate, it can be assumed that several CT scans will be performed during their lives (Patatas, Panditaratne, Wah, Weston, & Irving, 2012). The radiation emitted from an abdominal CT is equal to 500 chest x-rays, and multiple patients were found to have five CT scans over a period of 10 years (Goldstone & Bushnell, 2008).

It may be possible that cumulative radiation exposure will likely become a public health issue for patients with a history of renal colic, as they are at increased risk for excessive radiation from imaging (Moak, Lyons, & Lindsell, 2012). Kanno et al. (2014) echoes this sentiment calling CT scans "hazardous" for those patients with urinary stones. Sohn, Clayman, Lee, Cohen and Mucksavage (2013) estimate that the "collective radiation dose and the associated risk of cancer to the U.S. population from medical imaging has increased six fold (sic) during the past three decades, primarily because of CT and cardiac nuclear medicine" (p. 233). While it is fairly well documented that recurrent CT scans can cause health concerns, the risk of developing cancer is relatively low.

The risk of fatal cancer is likely 1 in 2,000 for 10 mSv of radiation, which is an average estimate of 1 CT scan; this risk increases to 1 in 133 for patients who have undergone multiple scans (Katz, Saluja, Brink, & Forman, 2006). In the U.S. in 2007, 29,000 malignancies that are diagnosed are thought to be attributed to CT scans (Moore & Scoutt, 2012). Therefore, risk of malignancy due to excessive CT scans is relatively low, about 2% (Shah et al., 2013).

While the CT scan is highly revered for its diagnostic accuracy for diagnosing kidney stones, it is not perfect and does not come without its downside. The increased cost without evidence of increased diagnosis, and the potential risk to a patient's health, while small, should make a case for an alternative diagnostic. Patients that have recurrent disease should definitely be considered for an alternate diagnostic that is less expensive and potentially less hazardous to the patient's health.

Imaging modalities have been thought to be essential when diagnosing suspected kidney stones; however, there is evidence to suggest simple laboratories and a watch and wait attitude may be sufficient in patients presenting with kidney stone symptoms.

Laboratories

Simple serum blood and urine laboratories can be useful in suspected kidney stone diagnosing. The specific gravity, pH, and noteworthy protein, nitrates, red blood cells, and bacteria found in a urinalysis can aid in the diagnosis of kidney stones (Goldfarb & Arowojolu, 2013). Specific gravity, or the sediment particles in the urine, can divulge calcium phosphate crystals if there is a pH of 6.5 to 7.0 (Goldfarb & Arowojolu, 2013). The presence of bacteria, nitrates, and/or trace to small red cells can reveal a urinary tract infection, as large amounts of red cells can point to a kidney stone. Protein may expose acute kidney injury or chronic disease.

While a urinalysis seems like a great option and is inexpensive, blood found in urine can denote many illnesses. Patients on their menses, patients with prostatitis, and patients with other bladder or urinary tract dysfunction can present with blood in their urine, making this diagnostic not as reliable as imaging. A small, but well-designed retrospective study reviewed patients with diagnosis or kidney stones via CT scan and urinalysis results; the results showed 84% sensitivity and 48% specificity, demonstrating that the finding of blood in urine is not predictive of kidney stones (Carter & Green, 2011).

A serum renal evaluation and serum electrolytes may be useful in kidney stones diagnostics and can be done easily. Assessing renal function may be the most useful as a decreased estimated glomerular filtration rate (eGFR) within the basic metabolic panel (BMP) can indicate nephrocalcinosis, which is calcium deposits within the kidney, dehydration, kidney disease, and can also signify recurrent stone obstructions and/or repeated urologic treatments (Sobol, 2015; Goldfarb & Arowojolu, 2013). Measuring a patient's blood urea nitrogen or BUN is also warranted and will help to determine appropriate diagnostics (Carter & Green, 2011). Electrolytes, within the BMP, including, potassium, bicarbonate, and calcium may be measured to evaluate stone presence. Hypokalemia or low serum potassium can indicate renal tubular acidosis, which is a sign of stone disease; as well as low serum bicarbonate (Goldfarb & Arowojolu, 2013). Elevated serum calcium can reveal a patient's affinity for stone formation, especially if hypercalciuria or high calcium in the urine is present (Goldfarb & Arowojolu, 2013). A comprehensive metabolic evaluation may not be cost effective for all patients with kidney stones, but may be considered in those with recurrent stones (Carter & Green, 2011).

While simple and cost effective laboratories can be useful in kidney stones diagnosis, the purpose of imaging, in a few cases, far exceeds the need for cost effectiveness. The next section will expound on this statement.

Finding Other Pathologies

There are many reasons why CT is considered the best modality for kidney stone diagnosis; however, imaging can also uncover unknown pathologies whether harmless or harmful to the patient. As a matter of fact, kidney stones are often incidentally uncovered in the workup of other conditions, but may be overlooked due to more detrimental diagnoses (Ray, Ghiculete, Pace, & Honey, 2009). The most common incidental findings are ovarian masses, pyelonephritis, diverticulitis, and appendicitis (Horner et al., 2005). Life threatening conditions, such as, an enlarging abdominal aortic aneurysm (AAA), acute thrombosis or infarction, and potentially cancerous masses are also included among the incidental findings (Hoppe, Studer, Kessler, Vock, Studer, & Thoeny, 2006). Almost 30% of patients that present with flank pain have a diagnosis other than kidney stones (Horner et al., 2005).

An incidental finding can be detrimental to a patient's health. In a small study of 1,500 patients, 6% had an incidental finding that required immediate attention, such as an acute thrombosis, infarction, or other conditions that could cause septicemia (Hoppe et al., 2006).Only 8% had a finding that required deferred treatment such as an abdominal aortic aneurysm larger than 5cm, enlarged lymph nodes or other chronic inflammatory conditions such as diverticulitis (Hoppe et al., 2006). Those findings that had little to no clinical importance were 31% and 26%, respectively (Hoppe et al., 2006). In four other studies, incidental findings that were deemed important was between 7-14%, with the diagnosis of a neoplasm <1% (Dalziel & Noble, 2013).

While it may appear that CT is invaluable for diagnosing incidental findings, those patients that are considered recurrent stone formers are knowledgeable about their symptoms. They are able to discern the similarities of sign and symptoms and voice that they feel as if they are passing another kidney stone. This information may make a significant argument for ultrasound as a possible diagnostic.

Current Practice Guidelines

The current practice of kidney stone diagnosis in the ED appears to be heavily reliant on CT scans; however, there is no accepted guideline for kidney stones or for recurrent kidney stones. There are two articles that explicitly say that if a patient presents with flank pain and has never formally been diagnosed as a kidney stone former; an initial CT scan may be warranted (Ha & MacDonald, 2004; Niemann, Kollmann, & Bongartz, 2008). Further, when a patient has been diagnosed as a kidney stone former, ultrasound as the initial imaging modality may also be applicable (Katz, Saluja, Brink, & Forman, 2006; Goertz & Lotterman, 2010). While imaging is important for reasons already stated, the most important factor for choosing an imaging modality is the patient. The provider should consider which modality is the safest, most effective for each patient and the burden or management of the stone.

Purpose of Imaging

Imaging has become a mainstay of diagnosing kidney stones because the purpose of imaging is not only to confirm the presence of a stone, but also to predict the outcome. Imaging can determine what the stone is composed of, where it is in the urinary tract, and how it will be managed. Accurate diagnosis is also paramount for those patients that have careers that put them at high risk for dehydration or with the inability to excrete urine, as they could possibly be a recurrent stone former and will need to institute certain lifestyle changes (Sandhu et al., 2003).

Stone Management

Once a kidney stone is suspected, management begins immediately. Management can include treatment, diagnosis, and planning of stone management. Pharmacological treatment is often times the first step in stone management, as kidney stones can be an acute, painful condition. Next, diagnostics, if applicable, may be done, and finally, management of the stone itself, which can include discharge to home or discharge to urologist, to consider stone removal options. Stone management will not be discussed at length in this paper, but is important for treatment of current and subsequent kidney stones.

Gaps in the Literature

In reviewing the literature, there were several findings that were lacking. While it is well documented among studies such as surveys, retrospective reviews, and prospective randomized control trials that CT scan is the superior imaging modality for diagnosing kidney stones, there is disagreement about alternative diagnostic modalities. Of the many articles reviewed, there were none that specifically discussed or studied recurrent stone formers and appropriate or alternative imaging modalities, and none that were specifically aimed at the practice patterns of NPs. More studies need to be done on recurrent stone formers, the diagnostics done and the efficacy, cost effectiveness and safety of the diagnostics.

METHODS

The purpose of this project was to describe NPs use of ultrasound to diagnose kidney stones in the ED. The information from this project was compared with the recent literature and then used to develop an evidence-based practice recommendation for diagnosing suspected kidney stones in the ED. Specific aims included: describing current diagnostic modalities among NPs working in the ED; comparing findings with extant literature; and developing a best practice recommendation for diagnosis of kidney stones in the ED. A cross-sectional, descriptive design was used to describe NPs use of ultrasound. The PDSA model was used to guide the specific steps of this DNP project.

There were four phases of the PDSA cycle. The first phase was the PLAN phase. The PLAN phase included several tasks, such as team recruitment, proposing an aim statement, describing current process, developing a problem statement, identification of barriers, and setting an alternative to the recommendation. In lieu of team recruitment, an academic advisor oversaw the project and provided feedback.

The second task was to create an aims statement, which was to capture practice patterns of nurse practitioners in the ED setting for diagnosing suspected urolithiasis. A review of current literature was compared with actual practice patterns and recommendations for best practices were developed.

The next task was to describe the current process. It is evident from the literature that the most common means of kidney stone diagnosis is through CT. Interestingly, while CT scans have increased over the last few years, kidney stone diagnosis has not increased (Westphalen et al., 2011).

The next three tasks were to develop a problem statement, identify barriers, and an alternative to the recommendation: The problem is that CT scans are expensive and are not without risk; in fact, repeated CT scans increased the risk of subsequent health concerns such as cancer (Moak et al., 2012). Barriers include the lack of a guideline in which to assist providers in making an informed decision based on evidenced-based practice. It is possible that utilizing an evidence-based practice guideline would help to decrease health care costs and unnecessary radiation to patients with kidney stones. The alternative is to continue utilizing CT scan for kidney stone diagnosis; it is possible however that the risks outweigh the benefits.

The second phase is the DO phase. For this project, a survey was developed based on extant literature, to determine current NP diagnosing practices, and attitudes toward using ultrasound in lieu of CT scans for diagnosing kidney stones. Surveys were sent out to nurse practitioners working in ED's across the country to describe their current practice in regards to kidney stone imaging, and to ascertain opinion of ultrasound as an alternative to CT scans.

The third phase is the STUDY phase. The STUDY phase of this project included analyzing the survey responses to describe current practice patterns of ED NPs diagnosing kidney stones. The results were then compared to the literature regarding CT and ultrasound for kidney stone diagnosis. The data was recorded and presented descriptively.

The fourth phase of the PDSA cycle is the ACT phase. In theory, this phase also consists of a change in practice and subsequent evaluation of change. For this project, the ACT phase includes the development of an evidence-based practice algorithm to guide the diagnosis of kidney stones among patients seen by NPs in the ED. In lieu of implementing the recommended practice change, I will discuss how I would evaluate the use of the algorithm to diagnose kidney stones in the ED.

Recruitment and Sample

Prior to recruitment, the Institutional Review Board (IRB) at the University of Arizona approved this survey and project. Disclosures were used in lieu of consent forms. The disclosure briefly outlined the study purpose, the risks and benefits, and the process should any participant have any concern.

Recruitment consisted of contacting the research coordinator for the American Association of Nurse Practitioners (AANP). The AANP charges a fee for each member address provided; therefore, in a discussion with my project chair, we agreed that I would recruit 200 participants. Two hundred recruitment packets were mailed to NP members of AANP who work in an emergency department. Each packet contained a disclosure, the survey, and a stamped envelope with my address on it.

In order to obtain responses from a wide variety of NPs working in EDs, inclusion criteria were minimal. No participants were required to hold ED certification, and in fact, the sample was comprised of NPs trained in acute care, adult care, and family practice. Additional inclusion criteria included advanced practice nurses who hold a master's degree or above, in nursing, who were fluent in written and spoken English, and whose home address was on file with the AANP.

Data Collection

Data was collected in the form of a survey. A 15-question survey was developed that focused on diagnostic imaging modality availability, and which modality was preferred for diagnosing kidney stones in the ED (Appendix A). Information about the amount and types of patients seen, and the capacity in which the NP worked in the ED was also collected. No personal identifiable information was collected. There was one open-ended question that inquired about the NP's attitude regarding use of ultrasound for diagnosing kidney stones.

Descriptive statistics were used to describe the data. Most of the questions provided dichotomous data. Four questions required the participant to select from several response options such as certification held, imaging modalities available in the ED, patient ED capacity, and the estimated number of patients with suspected kidney stones per month. One question employed a 'fill in the blank' format that addressed what protocol, if any, is being used in the ED to diagnose kidney stones. One open-ended question was included in the survey, which asked participants to describe their attitudes toward the use of ultrasound in the ED. The survey is located in Appendix A.

RESULTS

There were 200 surveys mailed out and 43 completed surveys were returned, which constitutes a response rate of 21.5%. According to Cobonoglu, Warde and Moreo (2001) mailed surveys have a response rate of 26%. While this is a lower response rate than a web-based survey method, the quality of the responses from either modality is usually similar (Cobonoglu et al., 2001). Nine surveys were returned with a note stating the NP did not meet the criteria outlined in the disclosure. Four surveys were returned with the first and third pages completed but without the second page; only the responses from the first and third pages were included in the analysis.

Demographics

The majority of participants (69.77%; N=30) self-identified as family nurse practitioners (Table 1). Some of the participants also self-identified as being both family and emergency certified (13%; N=6). Only 11.63% (N=5) self-identified as being acute care certified. One participant self-identified as adult-gerontology certified, and one respondent did not specify his or her specialty focus.

TABLE 1. *Demographics of NPs Surveyed.*

Nurse Practitioner Specialty	Percentage	Number of Respondents
Family Practice	69.77%	30
Acute Care	11.63%	5
Emergency Certification	13.95%	6
Clinical Nurse Specialist	0%	0
Other	4.65%	2

Survey Analysis

The survey results are shown in Table 2. All of the participants (100%; N=43) reported they evaluate patients with suspected kidney stones. Participants were asked to specifically identify the number of patients seen monthly for suspected kidney stones; the responses varied widely, with at least one participant having some months where no patients present with suspected kidney stones. At the other end of the spectrum, 5% (N=2) reported evaluating more than 150 patients per month for suspected kidney stones.

Participants were asked to identify how many patients their ED could accommodate at any one time. There was a wide range of responses, with a slight majority (41%; N=18) reporting the ability to accommodate 20-50 patients in the ED. One participant reported being able to accommodate more than 100 patients in the ED at any time. I did not look at any correlation between size of ED and prevalence of patients with suspected kidney stones seen by the NP.

Participants were asked to identify access to imaging modalities. All of the participants (100%; N=43) identified having access to imaging modalities for diagnosing possible kidney stones. CT access in the ED was universal. X-ray access was available to the majority of participants (82%; N=35), as was ultrasound (79%; N=34) and MRI (55%; N=24).

Participants were asked which modality they use to actually diagnose kidney stones. Unanimously, participants reported using CT to make the diagnosis of kidney stones. While the majority of participants (82%; N=35) have access to bedside ultrasound in the ED, only 40% (N=17) actually use ultrasound to diagnose kidney stones. Furthermore, although a small number of participants (13%; N=6) have the training to use ultrasound at the bedside, many (63%; N=27) do have 24-hour access to an ultrasound technician. One participant reported having access to an alternate technology to diagnose kidney stones; however, the alternate modality was not identified.

Participants were asked how the gender and age of the patient affects the diagnostic modality. Specifically, participants were asked to consider diagnosis of kidney stones in a female of childbearing age. The majority (69%; N=30) does take possible pregnancy into consideration when ordering diagnostics. I did not ask what imaging modality is used when pregnancy is a consideration. Consequently, slightly over one-third of the respondents reported they do not consider females for an alternate modality, but I did not ask what was used instead to diagnose.

Although there are no national standards or guidelines for diagnosing kidney stones in the ED, I was curious to know if any participants have access to or utilize a local or hospital-based protocol or guideline. Participants were asked if any guidelines or protocols were utilized in their ED, and if so, to identify the diagnostic modality named in the protocol. In fact, a slight majority of participants (40%; N=17) actually do utilize such a guideline or protocol. Unfortunately, only six offered a comment identifying the diagnostic modality: three used ultrasound, two used CT, and one reported using CT only if the patient reports no previous history of kidney stones (see Appendix B for responses).

TABLE 2. *Survey Questions with Descriptive Statistics.*

Survey Question	Answer	Percentage	Number of Respondents	Mean	SD	Min	Max
1. Which specialty best represents your advanced practice education?	Family Practice Acute Care Emergency Cert CNS Other	69.77% 11.63% 13.95% 0% 4.65%	30 5 6 0 2	1.58	1.05	1	5
2. Do you evaluate patients with flank pain, suspected kidney urolithiasis?	Yes No	100% 0%	43	1.00	0.00	1	1
3. How many patients can your ED hold at any one time?	1-10 10-20 20-50 50-100 100+	20.93% 13.95% 41.86% 20.93% 2.33%	9 6 18 9 1	2.70	1.10	1	5
4. In your estimate, how many patients present with flank pain, suspected urolithiasis per month?	0-20 20-50 50-100 100-150 150+	34.88% 30.23% 23.26% 6.98% 4.65%	15 13 10 3 2	2.16	1.13	1	5
5. Do you have access to imaging modalities for diagnosing?	Yes No	100% 0%	43	1.00	0.00	1	1
6. Do you utilize diagnostic imaging to diagnose kidney stones?	Yes No	97.37% 2.63%	42 1	1.02	0.16	1	1
7. What imaging modalities are available to you?	Basic (x-ray) Ultrasound CT MRI Other	81.58% 78.95% 100% 55.26% 2.63%	35 34 43 24 1	1.50	0.29	1	5
8. Do you use CT to diagnose kidney stones?	Yes No	100% 0%	43 0	1	0	1	1

TABLE 2 - *Continued*

Survey Question	Answer	Percentage	Number of Respondents	Mean	SD	Min	Max
9. Does your ED have access to bedside ultrasound?	Yes No	81.58% 18.42%	35 8	1.18	0.39	1	2
10. Are you trained to perform bedside ultrasound?	Yes No	13.16% 86.84%	6 37	1.87	0.34	1	2
11. Do you use ultrasound as a diagnostic tool for kidney stones?	Yes No	40.48% 59.52%	17 26	1.59	0.49	1	2
12. Does your ED have around the clock access to an ultrasound technician?	Yes No	62.79% 37.21%	27 16	1.37	0.49	1	2
13. Is your choice of diagnostic imaging influenced if the patient is a female of childbearing age?	Yes No	69.05% 30.95%	30 13	1.31	0.47	1	2
14. Do you currently use a guideline or standardized protocol to evaluate kidney stones?*	Yes No	40.48% 59.52%	17 26	1.59	0.49	1	2

*****This question also asked participants to fill in the blank. See Appendix B.*

Attitudes Toward Ultrasound

In one open-ended question, respondents were asked to describe their attitude toward use of ultrasound to diagnose kidney stones. Three respondents did not offer a response. Of the 41 responses, I identified six commonalities among the statements. The following discussion elaborates on these commonalities.

Nearly half of the responses (42%; N=18) indicated that ultrasound may provide a useful means to diagnose kidney stones in the ED. Benefits included reduced cost and less risk to the patient. As ultrasound is less expensive to operate, and does not emit harmful radiation to complete the exam. As one participant noted, ultrasound is "*cheaper and less harmful than CT.*"

The responses also indicated that if ultrasound is readily available, it could be efficient. Some of the participant's statements indicated that if ultrasound were available to them for diagnosing, it could be done quickly. This would make diagnosing kidney stones faster for patients.

Ultrasound may be considered as a viable means for diagnosing kidney stones in pregnant women. Three of the participants reported they would only consider using ultrasound for pregnant women. Further, the same three participants stated their belief that CT is preferred for diagnosing kidney stones. For example, "*it* (ultrasound) *is beneficial in pregnant patients-otherwise I prefer CT.*"

CT appears to be the preferred means of diagnosing kidney stones for at least 23% (N=10) of those surveyed. For those who do prefer CT as a diagnostic tool, it was generally seen as more efficient and accurate than any other modality. Other reasons included finding alternate pathologies that may need immediate intervention. One participant stated, "*we rarely use ultrasound to diagnose kidney stones; CT is preferred.*"

Ultrasound may be of benefit for diagnosing kidney stones if the patient has had at least one previous episode of kidney stones, diagnosed by CT. At least three participants indicated their willingness to use ultrasound for these patients, again as long as a previous CT is documented. As one participant describes, "*we normally do a stone study (CT), if proven kidney stones once, then usually don't repeat in the future.*"

Bedside ultrasound may be useful in the ED to diagnose kidney stones. Participants indicated that they would use bedside ultrasound (US) if it was available and they were trained to use it. "*I would use US in the diagnostic process in evaluation for kidney stones if trained.*"

A universal guideline for diagnosing kidney stones could be accepted by NP providers in the ED. Two of the participants stated their readiness on the evidence-based research regarding diagnosing kidney stones. This statement explicitly states this, "*I would like to see universal guidelines around this practice.*"

DISCUSSION

This study describes NPs' use of imaging modalities to diagnose kidney stones in the ED. Unanimously, participants reported using CT to diagnose kidney stones. While not all participants responded to the open-ended question regarding use of ultrasound as a means to diagnose kidney stones, the overarching theme was CT as the preferred means to diagnose. CT was viewed as the most efficient and accurate diagnostic modality. This mirrors findings from Ray et al. (2010), who content that CT is the most reliable and accurate means to diagnose kidney stones. Additionally, CT is viewed as quick, efficient, and the most reliable means to assess the number of kidney stones, their size and location (Pfister et al., 2003; Ulusan et al., 2007).

Significantly less of the respondents in this study (38%) reported using ultrasound for diagnosing kidney stones. However, almost half of the respondents indicated that ultrasound might also be useful for diagnosing kidney stones. Furthermore, those willing to consider ultrasound viewed ultrasound as more cost-effective and safer for the patient. Although there is not an abundance of research addressing ultrasound to diagnose kidney stones, the same issues of improved patient safety and reduced costs have been identified in the literature (Gaspari et al., 2005; Ulusan et al., 2007).

CT scans are often the first imaging studies employed for suspected kidney stone diagnosis, but may not always be the most appropriate means of diagnosis. CT is recommended for patients who present with new onset flank pain, who have never previously been diagnosed with kidney stones (Ha & MacDonald, 2004). CT can help to rule out other pathologies. Once a history of kidney stones is established, ultrasound may be more appropriate and less risky than CT (Goldstone & Bushnell, 2008; Hoppe et al., 2006). Some of the participants in this survey, who saw ultrasound as a less risky and more appropriate means to diagnose repeated kidney stones, echoed this.

Evaluating flank pain among females of childbearing age may cause health care practitioners to consider an imaging modality other than CT. While at the time of this literature review there were very few published studies that described risks associated with CT in pregnant women, Patatas et al. (2012) and Chowdhury et al. (2007) do purport that quality patient care necessitates non-radiological means to diagnose kidney stones in pregnant women. In this study, the majority of respondents (69%, N=30) reported they do not use CT to diagnose kidney stones among females of childbearing age. However, three participants use CT to diagnose kidney stones unless the patient is actually pregnant.

To date, there is no universally accepted protocol to diagnose kidney stones. In this study, a slight majority of participants (40%; N=17) reported using a hospital-based protocol. A small amount of participants (4%; N=2) indicated the desire for a kidney stone diagnosis protocol/guideline. The desire for a practice guideline echoes findings in the literature that a guideline or protocol for patients presenting with flank pain would assist decision-making (Brown, 2006), improve practice patterns (Hymas et al., 2011), limit the number of repeated CT scans (Broder et al., 2007) and ultimately improve quality patient care for patients with suspected kidney stones (Dalziel & Noble, 2013).

A large majority of the participants (81%; N=35) reported bedside ultrasound was available to them in the ED, even though very few participants actually have the training to use ultrasound. Some of the participants (19%; N=8) reported that using bedside ultrasound would be quick, cost-effective and a safer option. While there was not a lot of literature regarding the use of bedside ultrasound and diagnosing kidney stones, bedside ultrasound was found to be cost-effective, quick, and safer for patients due to the lack of radiation (Dalziel et al., 2013; Goertz & Lotterman, 2010).

Implications for Practice

Results from this study echoed many findings from the literature, which helps to outline the pros and cons of CT, alternate diagnostic imaging modalities, and the potential benefits of a universal algorithm for diagnosing kidney stones in the ED. Ultrasound may provide an alternate to CT scan. Additionally, ultrasound can even be delivered portably, at the bedside. Ultrasound does not emit radiation, and can be performed quickly right in the ED. It can make diagnosing stones more efficient, thereby allowing the patient to receive prompt treatment and reducing ER wait times and length of stay. It is even possible that NPs could obtain training and certification to utilize bedside ultrasound.

Females of childbearing age should be considered for an alternate diagnosing modality. Radiation to the female reproductive organs should be avoided. An alternate modality should be absolute to those women already pregnant. Radiation to the reproductive organs can be detrimental to the patient, and to any future pregnancies.

Ultrasound may present a viable alternative to CT for diagnosing kidney stones in patients who have significant claustrophobia or who cannot safely fit within the CT chamber due to obesity.

When an ED is inundated with victims of trauma and CT rooms are occupied, ultrasound may be a more expedient means to assess patients with kidney stones; this would enable the patient to obtain earlier diagnosis and treatment.

The results from this project and the peer-reviewed literature were used to develop an algorithm to diagnose kidney stones among patients seen in the ED. The goal of developing the algorithm was to help ED NPs consider ultrasound as an alternative to diagnosing kidney stones, thereby reducing the repeated use of CT. Utilizing alternative imaging modalities for those patients with suspected kidney stones may reduce healthcare costs and decrease potentially harmful radiation. The use of bedside ultrasound could also decrease patient wait times, length of stay, and further decrease healthcare costs. The following section describes the algorithm.

Algorithm: Diagnosing Kidney Stones for the Emergency Department

The purpose of the algorithm is to provide a decision-making guideline for diagnosing kidney stones in the ED. When a patient presents to the ED with flank pain, he or she should be asked to describe symptoms. The patient should be asked about kidney stone history; if a positive history is elicited, comparing current symptoms with past symptoms may help to further diagnose. If the patient has no previous history of kidney stones, a CT is recommended to help rule out other pathology and confirm presence of kidney stones. Simple laboratories, such as urinalysis, will assist the practitioner with the diagnosis, as hematuria in urine can indicate kidney stones. Females of childbearing years should always be considered for an alternate modality.

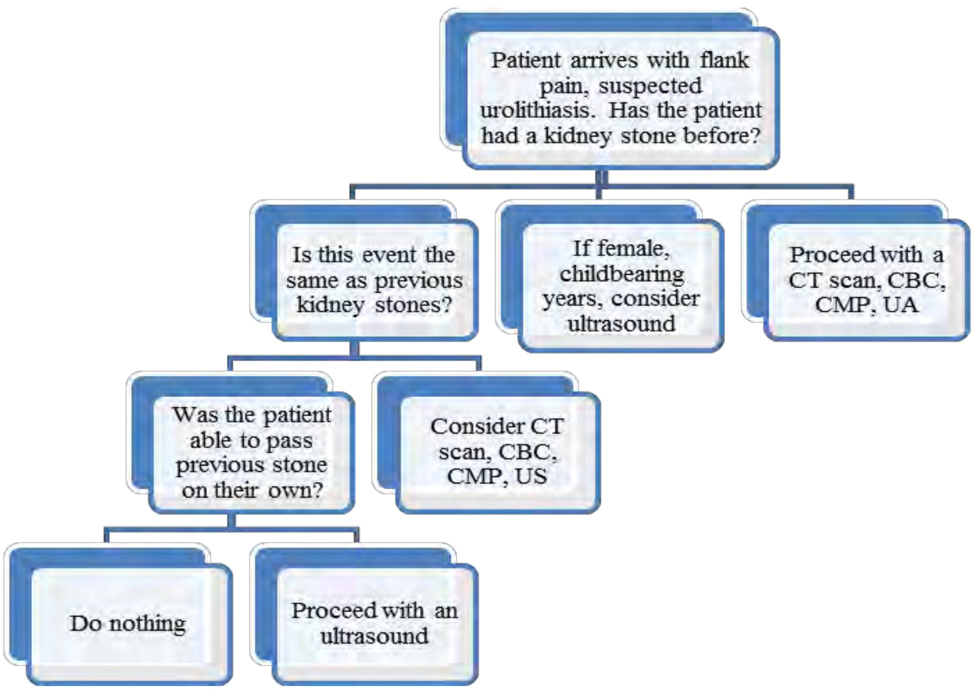

FIGURE 1. Kidney Stone Diagnosing Algorithm.

The fourth stage of the PDSA cycle is the ACT stage. Theoretically, this would consist of implementing the algorithm into practice. Since I am not actually implementing the algorithm, I will discuss how it would be evaluated for success.

Decreased use of CT scans to diagnose kidney stones would indicate a successful outcome. With the reduction of CT scans, the cost to the patient should decline and patient safety should improve. Ultrasound use would increase for patients who repeat to ED, and women of childbearing age would always be considered for an alternate diagnosing modality. Declines in healthcare costs, and safer options for diagnosing kidney stones would prove the algorithm success.

Study Limitations

The study consists of a relatively small sample size. Although 200 surveys were mailed out, only 46 were returned. The sample consisted of NPs working in emergency departments; therefore, the findings cannot be generalized to any other health care practitioners. Only a small number of participants actually discussed the use of ultrasound, and most had limited experience with ultrasound.

Conclusions

While CT scan is preferred and is considered the most accurate and reliable method for diagnosing kidney stones; it may be overused. The consequences of repeated CT scans or highly radioactive imaging modalities have been well documented not only as unsafe but expensive. CT scan is readily available, reliable, accurate and efficient for diagnosing kidney stones. However, ultrasound is safer, less costly, and can be readily available at the bedside to reduce healthcare costs. A diagnosing algorithm may help NPs make an evidence-based decision for diagnosing kidney stones in the ED.

APPENDIX A:

SURVEY: NURSE PRACTITIONERS USE OF ULTRASOUND

Nurse Practitioners Use of Ultrasound in the Emergency Department for Diagnosing Urolithiasis

Please circle the answers that best fit your practice.

1. Which specialty best represents your advanced practice education?	Family Practice	Acute Care	Emergency Certification	Clinical Nurse Specialist	Other_______
2. Do you evaluate patients with flank pain, suspected urolithiasis?	Yes	No			
3. How many patients can your emergency department hold at any one time?	0-10	10-20	20-50	50-100	100+
4. In your estimate, how many patients present with flank pain, suspected urolithiasis per month?	0-20	20-50	50-100	100-150	150+
5. Do you have access to imaging modalities for diagnosing?	Yes	No If you choose no, your survey is complete. Please mail back.			
6. Do you utilize diagnostic imaging to diagnose kidney stones?	Yes	No			
7. What imaging modalities are available to you? (Circle all that apply.)	Basic radiology or x-ray	Ultrasound (US)	Computed Tomography (CT)	Magnetic Resonance Imaging (MRI)	Other_______

8. Do you use CT scan to diagnose kidney stones?	Yes	No			
9. Does your ED have access to bedside US (ultrasound)?	Yes	No			
10. Are you trained to perform bedside US?	Yes	No			
11. Do you use US as a diagnostic tool for kidney stones?	Yes	No			
12. Does your ED have around the clock access to an US technician?	Yes	No			
13. Is your choice of diagnostic imaging influenced if the patient is a female of childbearing age?	Yes	No			
14. Do you currently use a guideline or standardized protocol to evaluate kidney stones?	Yes	No			

15. What is your attitude toward using US to diagnose kidney stones?

____

____

____

APPENDIX B:

RESPONSES TO TYPE OF PROTOCOL USED IN THE EMERGENCY DEPARTMENT

NP	*Fill in the blank response to the question:* **Do you currently use a guideline or standardized protocol to evaluate kidney stones**?
1	metabolic panel UA HCG-if needed NS, Toradol, Zofran CT without contrast abd/pelvis if high suspicion and no previous hx or remote hx. If frequent stones discussed options to try pain meds & Flomax & f/u with urology
2	ultrasound 1st if continues to c/o pain then CT scan
3	UA location of pain hx of kidney stones US
4	+ hematuria, noncomplicated, no hx, give meds, US kidneys, re-eval, if complicated, CT indicated
5	if no Hx of renal colic imaging required is CT if Hx of renal colic US is used
6	U/A BMP (kidney function) CT without contrast

APPENDIX C:

RESPONSES TO THE OPEN-ENDED QUESTIONS

Commonalities	*Responses to open-ended question:* **What is your attitude toward using ultrasound to diagnose kidney stones?**
1. Ultrasound could be useful as an alternate diagnostic modality for diagnosing kidney stones.	• Love it, less rads • It is an effective tool • Great if it is readily available • Worthwhile • Good • less invasive • Great • Excellent tool. Use it all the time • Cheaper and less harmful than CT • I would appreciate US to avoid excess radiation from CT • If it's reliable then let's do it! All for decreasing the number of CT scans on patients • I think it can be very useful tool and lowers ionizing radiation risk • I think it is awesome if available at your facility. I would be all for is as it decreases exposure to radiation • Would prefer non-ionized radiation method whenever possible • *Useful when it is positive; depending on pt presentation can be tricky if negative. Definitely use in pts w recurrent/freq presentations for kidney stones/flank pain • *It's quick, relatively painless. It is more tech proficient dependent and sometimes I get a pt who's kidney stone only seen on CT scan • My understanding is that US is less accurate in pts with larger body habitus. If as accurate and available would love to use in ER • *helpful unless complicated pt who surgeon requests CT
2. Ultrasound should only be used in pregnant women.	• I think it can have a high false negative rate. I only use it in pregnancy • *Although there is increased risk with CT (radiation) I feel this gives me a better answer. There seem to be more misses and less accurate diagnosis w US. I usually only use this for my pregnant population

	• *It is beneficial in pregnant patients-otherwise I prefer CT bc other potential problems can be identified in a timely manner
3. CT is preferred to ultrasound for diagnosing kidney stones.	• If there is no CT, it is good to have US • *Standard of care in our ED is to do a CT. When just US is ordered, a CT is recommended for definitive diagnosis by radiologist. Frustrating, bc of increased cost to patient. So often, it is easier to go with a CT • *Although there is increased risk with CT (radiation) I feel this gives me a better answer. There seem to be more misses and less accurate diagnosis w US. I usually only use this for my pregnant population • It is beneficial in pregnant patients-otherwise I prefer CT bc other potential problems can be identified in a timely manner • It is not as accurate as CT • Sometimes it isn't just about the diagnosis of kidney stones, may need to assess for obstruction, pyelo which is not visible on US • In my experience, I've had pts come to the ER for flank pain & they have recently had renal US that did not find a stone, however, we find stones on those same pts w a renal CT in the ER • *It's quick, relatively painless. It is more tech proficient dependent and sometimes I get a pt who's kidney stone only seen on CT scan • We rarely use US to diagnose kidney stones; CT is preferred • *helpful unless complicated pt who surgeon requests CT

4. Ultrasound should be used for patients that repeat to the ED, if a CT had been previously documented.	• We just started using it more in my ED. Beneficial for bounce backs that had CT few days prior or pts that are drug seeking or hx of frequent. Nice to have baseline CT • We normally do stone study (CT), if proven kidney stones once, then usually don't repeat in the future • *Useful when it is positive; depending on pt presentation can be tricky if negative. Definitely use in pts w recurrent/freq presentations for kidney stones/flank pain
5. Bedside ultrasound could be useful for diagnosing kidney stones quickly. (Many of the NPs denote they need training.)	• I need training to use it • I have not been trained to use US to diagnose kidney stones • Excellent idea, would need training • I would love to have reliable US coverage the ability to have bedside US w appropriate training to use in diagnosing kidney stones among other conditions • I would use US in the diagnostic process in evaluation for kidney stones if trained • I am in favor of using US. I work in a facility with immediate access to CT. US would be helpful in smaller EDs with no CT access, and trained providers • We need to use more often but access/time constraints make it prohibitive. I am not confident in my bedside US skills to make a dx. • I would love to obtain training and use US. CT scans are our current "habit" of practice in my rural ED. It would take a lot of convincing to change practice. Loss of revenue to x-ray dept.
6. A standardized guideline and evidence-based education could be accepted.	• I would like to see universal guidelines around this practice • Would like to be educated further on EB research regarding the effectiveness of using US to diagnose kidney stones
7. Other	• Don't know how effective or easy this is • No opinion

APPENDIX D:

THE UNIVERSITY OF ARIZONA IRB APPROVAL

THE UNIVERSITY OF ARIZONA

Date: September 01, 2015

Principal Investigator: Amanda M Schmidtmann

Protocol Number:	1508067060
Protocol Title:	Nurse Practitioners Use of Ultrasound to Diagnose Kidney Stones in the Emergency Department
Level of Review:	Exempt
Determination:	Approved

Documents Reviewed Concurrently:

HSPP Forms/Correspondence: *F107 v2015-07-Schmidtmann.doc* **HSPP Forms/Correspondence:** *Schmidtmann IRB 8-24.doc* **HSPP Forms/Correspondence:** *Signature page.pdf* **Informed Consent/PHI Forms:** *DISCLOSURE FORM 8-19.pdf* **Other Approvals and Authorizations:** *Schmidtmann LOS.pdf* **Participant Material:** *Survey 8-19.doc* **Recruitment Material:** *Email.doc*

This submission meets the criteria for exemption under 45 CFR 46.101(b). This project has been reviewed and approved by an IRB Chair or designee.

The University of Arizona maintains a Federal wide Assurance with the Office for Human Research Protections (FWA #00004218).

- All research procedures should be conducted in full accordance with all applicable sections of the Investigator Manual.
- Exempt projects do not have a continuing review requirement.
- This project should be conducted in full accordance with all applicable sections of the IRB Investigators Manual and you should notify the IRB immediately of any proposed changes that affect the protocol.
- Amendments to exempt projects that change the nature of the project should be submitted to the Human Subjects Protection Program (HSPP) for a new determination. See the Investigator Manual, 'Appendix C Exemptions,' for more information on changes that affect the determination of exemption. Please contact the HSPP to consult on whether the proposed changes need further review.
- You should report any unanticipated problems involving risks to the participants or others to the IRB.
- All documents referenced in this submission have been reviewed and approved. Documents are filed with the HSPP Office. If subjects will be consented, the approved consent(s) are attached to the approval notification from the HSPP Office.

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