Diagnostic efficacy of computed tomography of the urinary tract for suspected acute urolithiasis

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Thesis submitted in fulfilment of the requirements for the degree

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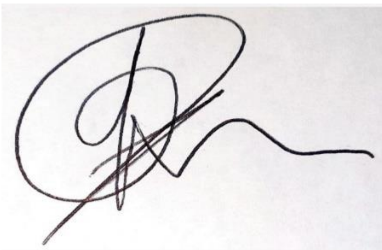
September 2020

DECLARATION

I, Georgell Shereeff Van Wyk, declare that the contents of this thesis represent my unaided work and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.



30 September 2020

Signed **Date**

ABSTRACT

Introduction

Multi-Detector Computed Tomography (MDCT) is the gold standard for investigating suspected acute urolithiasis. Unenhanced Computed Tomography of the kidneys ureters and bladder (UECT KUB), performed for suspected urolithiasis, have high detection rates for uroliths and non-urolithiasis related pathology. Technique variations during UECT may sometimes prove beneficial to the patient management process. Evaluation of the efficacy of a current radiographic imaging protocol may substantiate the need for a protocol and allow for improved patient management.

Objectives

The main aim of the study was to evaluate the effectiveness of an imaging protocol for suspected acute urolithiasis on three levels of efficacy. The objectives of this research were to firstly investigate the detection rate of urolithiasis as a parameter of diagnostic accuracy efficacy (DAE). Secondly to evaluate the detection rate of non-urology pathology as a parameter of diagnostic thinking efficacy (DTE) and thirdly to determine the contribution of UECT to the patient management process as a parameter of therapeutic efficacy (TPE).

Methods

A retrospective cross-sectional study was conducted at a private hospital in the Cape metropole by collecting data from the Picture Archiving and Communication System (PACS). Records from 01 January 2010 up to and including 31 December 2017 of 753 patients, referred for suspicion of acute urolithiasis were reviewed. A total of 449 records that matched the inclusion criteria were analysed. Records indicating urolithiasis were separated from records indicating non-urolithiasis related pathology for measurement of DAE and DTE. Records indicating urology intervention were grouped for measurement of TPE. Characteristics of grouped records were assessed to explain DAE, DTE and TPE outcomes.

Results

The total number of positive cases for urolithiasis during UECT KUB was 35% (n=159). From the sample, 16% (n=113) of records indicated non-urolithiasis related pathology. Gastrointestinal pathology accounted for the highest incidence at 32% (n=37) with other urinary tract pathology following at 28% (n=32). Urologic intervention was indicated in 46% (n=201) of patients identified with urolithiasis.

Conclusion

The urolith amount and size were found to increase intervention rates. Urolith size larger than 5mm was a determining factor that influenced the therapeutic rate for urolithiasis at the study site. It is recommended that the current protocol of prone rescanning is not indicated in cases where urolith size is < 5mm as intervention rates are not influenced by the scanning position. In cases where UECT KUB excluded urolithiasis, other pathologies were detected for further medical referral. The imaging protocol currently used at the research site is optimal for diagnosing the presence and magnitude of urolithiasis and for providing a management pathway for patients.

Keywords: Efficacy, UECT KUB, urolithiasis, imaging protocol

ACKNOWLEDGEMENTS

I want to thank:

- Mrs Florence Davidson, for all her time and effort, spent during this project.
- Mrs Valdiela Daries, for encouragement throughout my years of study since I enrolled as a first-year student.
- Prof. D. J. van Schalkwyk for his assistance with statistical analysis.
- Mrs Thembi Seth, for her patience and assistance.
- The Faculty of Health and Wellness Sciences, for this opportunity.
- The entire MITS department, for their effort and assistance.
- My wife Lowena Van Wyk for all her patience and support.

Abbreviations and acronyms

List of abbreviations and acronyms	Explanation
3D	Three Dimensional
ACR	American College of Radiologists
AIVC	Anterior Iliac Vessel Crossing
ALARA	As Low As Reasonably Achievable
ARV	Anti-Retroviral
CECT	Contrast-Enhanced Computed Tomography
CT	Computed Tomography
CTU	Computed Tomography Urography
DAE	Diagnostic accuracy efficacy
DTE	Diagnostic thinking efficacy
ED	Emergency Department
EHL	Electrohydraulic Lithotripsy
ESWL	Extracorporeal Shock Wave Lithotripsy (ESWL)
GFR	Glomerular Filtration Rate
GIT	Gastrointestinal Tract
HU	Hounsfield Unit
IVU	Intravenous Urography
KUB	Kidneys Ureters and Bladder
MDCT	Multi-Detector Computed Tomography
MSK	Musculoskeletal
NSAIDs	Non-Steroidal Anti-Inflammatory Drugs

PACS	Picture Archiving and Communication System
PCN	Percutaneous Nephrostomy
PCNL	Percutaneous Nephrolithotomy
POE	Patient outcome efficacy
PUJ	Pelvic-Ureteric Junction
SE	Societal efficacy
TE	Technical efficacy
TPE	Therapeutic efficacy
UECT	Unenhanced Computed Tomography
UECT KUB	Unenhanced Computed Tomography of the Kidneys, Ureters and Bladder
URS	Uretero Renoscopy
UVJ	Ureterovesical Junction

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CHAPTER ONE: INTRODUCTION

Urolithiasis has become a common urinary tract disease, with a high prevalence in developed countries (Meissnitzer *et al.,* 2017). An estimated 1.2 million Americans and close to 1 million Europeans are affected annually (Meissnitzer *et al*., 2017). Research on urolithiasis in the African continent indicates that there are regions where urolithiasis diagnosis is uncommon. Southern Africa is particularly unique in that certain population groups are prone to develop urolithiasis while in other population groups urolithiasis is rare (Rodgers, *et al.,* 2009). Rogers *et al.,* 2009 note that the absence of urolithiasis in the black population of Southern Africa (SA) has not been fully explained. However, the susceptibility to urolithiasis of white and black populations as previously noted seem to be more prevalent with westernized diets no matter the race (Rodgers, *et al*., 2009).

Unenhanced Computed Tomography (UECT) serves as the gold standard for the diagnosis of acute renal colic (Meissnitzer *et al.,* 2017). The use of UECT of the kidneys ureters and bladder (KUB) was documented in 1995, for its usefulness in diagnosing acute urolithiasis (Chowdhury *et al.,* 2007). UECT KUB has several obvious advantages to treatment paths for urolithiasis. For example, there is no need for intravenous contrast media administration, the examination time is short, and there is increased sensitivity and specificity for the detection of urolithiasis and other causes of flank pain (Chowdhury *et al.,* 2007).

When urine contains an abnormally high concentration of salts, it may cause crystallization. The single product of crystallized urine in the urinary tract is known as a urolith. A urolith may typically form in the kidney and migrate further down the urinary tract (Scales, *et al.,* 2012). During the migration of a urolith down the urinary tract, it may cause severe pain and irritation of the epithelium and subsequently hematuria (Seitz & Fajkovic, 2013). Obstruction by uroliths commonly occurs in areas of luminal narrowing secondary to a change in anatomy. The pelvic-ureteric junction (PUJ), the level of ureteral passage over the pelvic brim, and the ureterovesical junction (UVJ) are typical locations for urolith occurrence. Therefore, extra attention should be paid to these sites and the entirety of the urinary tract for identification of possible lodged uroliths (Cheng *et al.,* 2012).

Urolithiasis is frequently encountered in emergency departments (Scales, *et al.* 2012). UECT KUB plays an important role in the management of patients with suspected acute urolithiasis (Andrabi, *et al.,* 2015; Brisbane *et al.,* 2016). Traditionally, the UECT KUB is performed in the supine position. However, in the case of UVJ uroliths, uncertainty may arise as to whether or not a urolith has passed into the bladder. Levine *et al.* (1996) were among the first researchers that investigated the ability of another projection to demonstrate passed uroliths*.* During their investigation, the authors proposed the prone projection from the outset. Since the study by Levine *et al.,* (1996) there is still a debate whether a standard supine CT imaging protocol for diagnosing suspected acute urolithiasis is required.

The expansion of medical imaging from primarily radiology, to virtual pathology slides and telemedicine, has brought these techniques under the efficacy magnifying glass. Krupinsky and Jiang (2008) believe that all new imaging technologies should be evaluated to assess the impact on patient management. Evaluating the efficacy of a radiological imaging protocol, in context, is important to guide decision making on a radiographic service level (Fryback & Thornbury, 1991). Fryback and Thornbury (1991) describe efficacy as the probability of optimal radiographic service to patients by an imaging protocol under ideal conditions of use. The aforementioned authors believe that an evaluation of the efficacy of radiographic protocols should be driven by a clinical question or task, which may be to characterize disease processes. Furthermore, depending on the clinical task, they suggest that experimental protocols and analytical tools used to evaluate imaging results often vary (Fryback & Thornbury, 1991). Krupinsky and Jiang, (2008:645) defined the different levels of efficacy as technical efficacy (TE), diagnostic accuracy efficacy (DAE), diagnostic thinking efficacy (DTE), therapeutic efficacy (TPE), patient outcome efficacy (POE), societal efficacy (SE).

Gazelle, *et al.,* (2011) note that each level in the hierarchy has an important influence on the next level and the parameters measured to maintain a balance. This balance enables the system to perform efficiently (Dalla Palma, *et al.,* 2001). However, each level of efficacy and subsequent parameters must be constantly evaluated to provide for the needs of the system objectives (Rucker, *et al.,* 2004). This hierarchy of efficacy will be further discussed and explained in chapter 2.

The use of CT in the clinical environment has improved with leaps and bounds over the last decade, which is evident in the radiation doses that are constantly being tailored to the clinical question especially with urolithiasis imaging (Kennish*, et al.,* 2008). Henceforth, the choice of imaging modality for disease detection depends on its safety, accuracy, adaptability, cost-effectiveness, availability, and ease of interpretation (Kirpalani, *et al.,* 2005). The next section will discuss the research rationale, the research question and research aim and objectives.

1.1 Research Rationale

This study was based on patients who presented at an emergency department of a private hospital in the Cape Metropole. Patients were referred to the radiology department for UECT KUB with suspicion of acute urolithiasis. At the specific radiology department (also the research site), as per departmental imaging protocol, a UECT KUB for suspected acute urolithiasis is performed in the supine position. The scan includes anatomy from above the kidneys to below the urinary bladder. The images are archived for subsequent viewing and interpretation by a radiologist.

At the research site, the UECT KUB imaging protocol for suspected acute urolithiasis can vary. For example, if a urolith is visualized at the UVJ, the radiologist may or may not request a prone rescan of the bladder. The reasoning behind the prone rescan is that the UVJ urolith will be demonstrated in a different position as opposed to the supine position. This will confirm if the urolith is located freely in the urinary bladder or if it is lodged in the UVJ.

This imaging protocol variation results in an increase in exposure to ionizing radiation. The time elapsed between waiting for the radiologist to confirm if a prone rescan is needed may result in more patient time spent in the radiology department. More patient time spent in the radiology department results in a delayed workflow system and, in some cases, patient dissatisfaction toward service delivery.

This research study was conducted to investigate the efficacy of the specific UECT KUB imaging protocol for suspected acute urolithiasis at the research site by evaluating three levels of efficacy thereof.

1.2 Research question

The research question of this research study was: “What are the factors influencing the diagnostic accuracy efficacy, diagnostic thinking efficacy and therapeutic efficacy of the UECT KUB for suspected acute urolithiasis at the research site?”

1.3 Research aim and objectives

The research study aimed to evaluate three levels of diagnostic efficacy of the current UECT KUB protocol performed at the research site.

The objectives of this research were:

- To investigate the detection rate of urolithiasis as a parameter of diagnostic accuracy efficacy (DAE).
- To evaluate the detection rate of non-urology pathology as a parameter of diagnostic thinking efficacy (DTE).
- To determine the contribution of UECT to the patient management process as a parameter of therapeutic efficacy (TPE).

For this research study, the following are hypothesized:

- H0 – The UECT KUB protocol for detecting acute urolithiasis is optimal concerning DAE, DTE and TPE.
- H1 – The UECT KUB protocol for detecting acute urolithiasis is not optimal concerning DAE, DTE and TPE.

1.4 Evaluation of efficacy at the research site

The Picture Archiving and Communication System (PACS) at the research site had data available for the evaluation of factors that contribute to three of the seven levels of efficacy (i.e. DAE, DTE and TPE) as described by Krupinsky and Jiang (2008). The following section describes the evaluation criteria of the three levels of efficacy assessed in the current study.

1.4.1 DAE of UECT KUB for suspected urolithiasis

Diagnostic accuracy efficacy evaluated the detection rate of acute urolithiasis and urolith location specifically. This characteristic directs patient management (Shoag *et* *al.,* 2015). During the evaluation of this level of efficacy, the frequency of urolithiasis was measured per location, how often a rescan in the prone position was performed and under what circumstances intervention was applied.

1.4.2 DTE of UECT KUB for suspected urolithiasis

Diagnostic thinking efficacy evaluated the clinician's estimate of the probability that the patient suffers from urolithiasis. Patient symptoms and final diagnosis were used as parameters for the measurement of clinical predictability for DTE. The rationale for UECT KUB requests could be validated by the final diagnosis from the records.

1.4.3 TPE of UECT KUB for suspected urolithiasis

Therapeutic efficacy evaluated intervention rates to see if any correlation exists between urolithiasis characteristics (i.e. amount, size and location). The effect that UECT KUB has on the course of treatment of a patient is a valuable predictor of the feasibility of UECT KUB in this context (Gazelle *et al.,* 2011)

1.5 Significance and possible contributions of this study

Urolithiasis is a common diagnosis in patients presenting with severe abdominal pain at emergency departments. This is often the case in an after-hour setting with a limited number of radiographers providing an imaging service to multiple departments in the hospital. Radiographers providing emergency service after hours are often limited by time constraints. Thus, patient referrals and imaging protocols need to be optimized to benefit workflow and patient outcomes.

CT is a high radiation-dose technique. The effective dose of UECT KUB has been estimated to be between 3 and 5 mSv (Patatas *et al.,* 2012). Referring physicians and patients are becoming increasingly aware of the safe and efficient use of imaging procedures. In most cases, diagnostic tests improve patient outcomes. Efficacy studies of radiographic procedures ensure the safe and efficient use of such procedures.

This research showed the efficacy of the UECT KUB protocol on three levels (DAE, DTE and TPE) at the research site and can be used to guide future protocols. It was found that the protocol is optimal for diagnosing the presence and magnitude of urolithiasis at the research site (DAE) as just over a third of patients referred had uroliths confirmed by UECT KUB. Furthermore, non-urolith pathologies (DTE) were also detected by the UECT KUB protocol, thereby allowing patient referral to the relevant specialists.

Prone re-scanning did not affect intervention rates which is an indication that patient workflow may be improved by eliminating the need to do prone positioning for suspected lodged UVJ uroliths. Patient management (TPE) was influenced by UECT KUB findings in that nearly half of those diagnosed with uroliths on CT had an intervention, with urolith amount and size affecting the intervention rates.

This chapter has provided an overview of the rationale for the research, the objectives thereof and its contribution to the existing body of knowledge. The next chapter describes urolithiasis, imaging thereof and the framework for evaluating an imaging protocol.

CHAPTER TWO: LITERATURE REVIEW

The literature review was conducted by searching electronic databases specifically Science Direct, PubMed, Scopus and Ebscohost as well as the academic search engine Google Scholar, for the keywords: Efficacy, CTKUB, prone, supine and urolithiasis.

2.1 Introduction

UECT KUB is an excellent means of investigation of suspected acute urolithiasis with sensitivity and specificity approaching 100% (Colistro *et al.,* 2002). At the study site, the standard UECT KUB protocol varies when a UVJ urolith is visualized. In some instances when UVJ uroliths have been detected with UECT, the radiologist required prone position scan of the bladder to determine if the uroliths were lodged at the UVJ. This research aimed to evaluate the efficacy of the UECT KUB protocol at the research site.

This literature review starts by discussing the pathogenesis, imaging techniques (specifically UECT KUB and the value thereof) and treatment pathways for different presentations of urolithiasis. In addition, the theoretical framework, for evaluating imaging protocols is also discussed.

2.2 Pathogenesis of urolithiasis

Reduced fluid intake appears to be the most common risk factor for the development of urolithiasis (Vijaya, *et al.,* 2013). Urolithiasis is more common in males and specifically affects those older than 30 years. Familial urolithiasis also increases the risk of urolithiasis (Vijaya, *et al*., 2013). Similarly, a previous urolith event increases the risk that a person will develop subsequent uroliths in the future (Vijaya, *et al.,* 2013). According to Evans (2010), certain medications can increase the risk of developing urolithiasis in some individuals. Medication used to treat seizures and migraines have been noted to increase the likelihood of urolith formation (Evan, 2010). Additionally, it is known that the long-term consumption of vitamin D and calcium supplements may contribute to urolith formation (Evan, 2010). Additional risk factors for urolithiasis include diets that are high in protein and sodium but low in calcium, an inactive lifestyle, obesity, hypertension and conditions that affect how calcium is absorbed in the body (Mehmet & Ender, 2015).

Urolith formation is related to sedimentation of crystallized urine fragments in the kidneys. This results in an inflammatory process and reduction of renal function (Mehmet & Ender, 2015). Obstruction of the urinary tract by uroliths may result in reduced renal blood flow and subsequently reduced glomerular filtration rate. (Miller & Lingerman, 2007). As the human body tries to expel these uroliths, they sometimes become lodged along the way. The most common sites of occurrence of uroliths are where the diameter of the ureters naturally narrows. These sites of narrowing have been noted to be where the diameter of the renal pelvis decreases to that of the proximal ureter (PUJ); the bifurcation of the iliac vessels (mid-ureter), where the ureter courses anterior-medial to the vessels, at the UVJ (Cheng *et al.,* 2012). As explained by Favus (2011) impaction of a urolith in these narrow points along the urinary tract can cause obstruction of the ureters resulting in urinary stasis above the obstruction. Infection from urinary stasis is considered a urological emergency (Noshad, *et al.,* 2014).

Initial urolith formation has been noted not to cause any symptoms (Alelign & Petros, 2018). However, Elton, *et al.,* (1993), has described several symptoms resulting from ureteral obstruction. These symptoms include but are not limited to severe abdominal pain, nausea, vomiting, hematuria (micro- or macroscopic) and in severe cases fever and sepsis (Alelign & Petros, 2018). Abdominal pain distribution due to a urolith may vary depending on the site of impaction. For example, uroliths at the PUJ have been observed to cause pain radiating to the flank while urolith occurrence at the level of the iliac vessels causes pain radiating down into the groin and lower abdomen (Brisbane et al., 2017). Uroliths impacted at the UVJ have been observed to cause pain that radiates into the genitals and may create urinary frequency, urgency, and dysuria, as the urolith irritates the bladder. The majority of impacted uroliths occur at the PUJ and UVJ (Brisbane *et al.,* 2017).

This section highlighted the development of urolithiasis, typical symptoms associated with urolithiasis and complications resulting from this condition. There are several radiological imaging examinations employed to aid the diagnosis of urolithiasis. Various treatment options are also available for the condition at varying stages of development; these are discussed in the next section.

2.3 Imaging for suspected acute urolithiasis

Patient preference, clinical status and symptom severity are the central parameters that guide the clinician when requesting radiological imaging examinations for urolithiasis (Patel & Patel, 2012). The following section discusses various radiological imaging examinations that may be utilized in a clinical context where patients present with suspected acute urolithiasis.

2.3.1 The plain abdominal radiograph for suspected urolithiasis

The plain radiograph of the KUB produces a two-dimensional image to investigate the urinary tract. This technique demonstrates urolithiasis due to the degree of radio-opacity (Patel & Patel, 2012) of uroliths. However, uric acid, xanthine and cystine uroliths are known to appear radiolucent on conventional radiographs (Andrabi, *et al*. 2015). In some cases, bowel gas, bony structures and patient body size are major limitations of plain abdominal radiographs when investigating urolithiasis (Patel & Patel, 2012). The KUB radiograph, however, is considered a safe and useful method for follow-up investigation due to the low radiation dose, ease of access and cost-effectiveness thereof (Patel & Patel, 2012). The limitations of plain radiography can be overcome with digital tomosynthesis (DTS) (Mermuys, *et al.,* 2010).

2.3.2 DTS for suspected urolithiasis

DTS examinations of the abdomen involve, an x-ray tube performing continuous linear movements across the abdomen and pelvis. A series of low radiation-dose projections are acquired with a digital detector during a single movement of the x-ray tube (Patel & Patel, 2012). According to Mermuys, *et al.,* (2010) these projections at different angles are combined to view sectional images of the abdomen that appears as individual coronal reconstructed slices. Slice spacing can be pre-selected to visualize specific anatomic structures. With larger patients, the number of reconstructions must be increased to visualize the anterior portions of the ureters during DTS for urolithiasis (McAdams, *et al.,* 2006).

The advantage of DTS is that bowel gas and other overlying anatomic structures are excluded from data acquisition (McAdams, *et al.,* 2006). Furthermore, DTS also provides important depth information of the anatomic structures (McAdams, *et al.,* 2006). Limitations of DTS are that only slices parallel to the detector plane can be obtained resulting in a dependence on patient positioning for its success. This slice selection brings about the loss of spatial resolution and blurring of the tissues outside brings about the loss of spatial resolution and blurring of the tissues outside of the slice selection. Specific slice selection during DTS of the abdomen for suspected acute urolithiasis limits the possibility of an overview of the entirety of the abdomen (Mermuys, *et al.,* 2010).

2.3.3 Intravenous urography (IVU) for suspected urolithiasis

Intravenous urography (IVU) has largely been outdated and replaced by CTKUB in recent years, as the latter has been observed to yield a higher sensitivity for the diagnosis of urolithiasis (Patel & Patel, 2012; Andrabi *et al.,* 2015). IVU also requires the administration of intravenous iodinated contrast agents. These contrast agents are used to opacify the collecting systems and are often contra-indicated for several reasons. However, IVU is of use in situations where CT is not available and exclusion of obstruction by radiolucent uroliths in the acute setting is needed (Andrabi *et al.,* 2015). Observation by Patel and Patel (2012) suggest that tomography can be used to further increase the sensitivity and definition obtained during the IVU series. This can be beneficial in planning intervention where intra-renal anatomy and precise calyceal localization is often better on IVU compared to UECT KUB (Patel & Patel, 2012).

2.3.4 Ultrasound for suspected urolithiasis

Ultrasound may also be used to diagnose urolithiasis in the acute setting (Andrabi *et al.,* 2015). The advantage of ultrasound relates to the smaller design of ultrasound equipment, easy transport thereof and no radiation, which is of great concern to the younger population during diagnostic imaging (Patel & Patel, 2012). Ultrasound is a safe and readily available imaging technique, but its sensitivity is operator dependent and influenced by the body habitus of the patient (Brisbane *et al.,* 2016). Increased body mass index is also known to be a limiting factor for an ultrasound examination. Detection of urolithiasis with ultrasound relies upon visualization of hyperechoic uroliths and any possible shadowing that it may cause (Andrabi *et al.,* 2015). The limited echogenicity of uroliths during ultrasound has also been observed to be a factor that reduces the accuracy of ultrasound for urolithiasis detection (Patel & Patel, 2012). There are limitations to ultrasound for diagnosing urolith smaller than 5mm as they tend not to cast acoustic shadows. Additionally, Patel and Patel (2012) indicate that ureteric uroliths are poorly demonstrated in most cases when investigated with ultrasound. However, when uroliths are situated within the proximal portion of the ureter or near the UVJ, ultrasound proves most valuable.

However, when uroliths are situated within the proximal portion of the ureter or in close proximity to the UVJ, ultrasound proves most valuable.

Brisbane *et al* (2016) state that ultrasound, however, does demonstrate alternate signs of obstructing uroliths such as hydronephrosis or hydro ureter and a ureteral jet using Doppler ultrasound. Ahmed *et al* (2010) explain that the visualization of ureteral jets, with ultrasound, is vital during exclusion of obstructive uropathy because secondary signs and symptoms of obstructive urolithiasis may persist even after uroliths have passed into the urinary bladder. Visualization of secondary signs of urolithiasis, including hydronephrosis, peri-renal fluid collection, and a change in the resistive index of an inter-lobar artery, are all important ultrasound findings (Ahmed *et al.,* 2010). When uroliths are revealed in the distal ureter, hydro ureter without dilatation of the renal pelvis might be seen and considered (Ahmed *et al.,* 2010). Ultrasound does not expose patients to ionizing radiation thus may be considered for pediatric patients, pregnant patients and follow-up evaluations for urolith passage (Brisbane *et al.,* 2016). The next section discusses another non-ionizing radiation modality for the detection of suspected acute urolithiasis.

2.3.5 Magnetic Resonance Imaging for suspected urolithiasis

The main advantage of Magnetic Resonance Imaging (MRI) is the ability to provide three-dimensional (3D) imaging without exposure to ionizing radiation (Brisbane *et al.,* 2016). In addition, MRI produces high tissue contrast and spatial resolution (Ibrahim *et al.,* 2016). During MRI of the KUB, both anatomical and functional information are acquired. This dual information acquisition is made possible with the various imaging parameters of MRI that can be adjusted to accentuate the visualization of certain tissues or physiological processes (Ibrahim *et al.,* 2016).

The sensitivity of MRI for suspected urolithiasis remains variable, and like ultrasound, can be increased by the presence of hydro-nephrosis as noted by Karabacakoglu, *et al.,* (2004). Ultra-short time to echo (TE) MRI sequences have increased the reliably of MRI for imaging the urinary tract (Brisbane *et al*., 2016). Robson, *et al.,* (2003) observed that uroliths only appear as a nonspecific signal void. When comparing sensitivities for urolith detection MRI was 82%, ultrasound 45% and plain radiography 37% while that of CT was 97% (Fulgham, *et al.,* 2013).

Unfortunately, various disadvantages of MRI prevent it from general use in urolith imaging. These disadvantages are the higher cost of MRI compared to that of CT and lower accuracy and longer image acquisition times compared to that of CT in imaging uroliths. In an acute setting, MRI is probably most appropriately prescribed in combination with ultrasound in patients that are pregnant (Brisbane *et al.,* 2016).

2.3.6 UECT KUB for suspected acute urolithiasis

UECT KUB is now the accepted gold standard imaging examination for acute urolithiasis due to its high diagnostic accuracy (Ahmed *et al.,* 2010; Patel & Patel, 2012; Andrabi *et al*., 2015). This imaging modality yields the highest sensitivity and specificity for suspected acute urolithiasis with figures approaching 100% accuracy (Brisbane *et al.,* 2016). Its accuracy, cost-effectiveness, availability, adaptability and ease of interpretation are what set it apart from the other radiological imaging examinations in this context (Rucker, *et al.,* 2004). Furthermore, if the symptoms are not caused by urolithiasis, CT can often identify the alternative cause (Kang *et al.,* 2014). The principle of UECT KUB is discussed in the next section.

2.3.6.1 Principle of UECT KUB for suspected urolithiasis

UECT KUB uses the differential absorption of radiation by body tissues (Brisbane *et al.,* 2016). Multiple data points are obtained by rotation of a radiation source and contralateral detector around the patient. This data is processed by a computer into axial, sagittal and coronal reconstructions (Rucker *et al.,* 2004). The review of sequential images on a workstation makes it easier to follow the ureters and thereby identify the exact location of any radio-densities within it. While the use of a workstation is not a necessity, it helps in identifying subtle uroliths and in solving common problems such as the differentiation of pelvic phleboliths from distal ureteric uroliths (Cheng *et al.,* 2012).

UECT KUB detects all types of uroliths, including uric acid, xanthine or cystine uroliths that are otherwise radiolucent on plain radiographs (Abdel Goad, & Bereczky, 2004). Uroliths have a markedly different composition compared to renal parenchyma and urine therefore; they absorb considerably more radiation and are easily identifiable without the need for contrast media injections (Brisbane *et al.,* 2016). CT generates a 3D image of the urolith and the surrounding anatomy. The most distinct advantage of CT is that it can acquire all this data within one breath-hold (Dalla-Palma, *et al.,* 2001). The next section will focus on the accuracy of data acquired during UECT KUB for urolithiasis.

2.3.6.2 Accuracy achieved with UECT KUB for suspected urolithiasis

The American College of Radiologists (ACR) estimates the accuracy of UECT KUB to be 98% when a patient presents with acute flank pain suspicious of an obstructing urolith. The accuracy of a diagnostic test may predict the presence, absence and magnitude of a disease i.e. diagnostic accuracy efficacy. Sensitivity, specificity, positive or negative predictive value and accuracy are the most commonly measured parameters during clinical effectiveness research (Gazelle *et al*., 2011). It is known that UECT KUB not only demonstrates the presence or absence of urolithiasis but also the magnitude thereof (i. e. location, amount of uroliths and size).

To date, research has demonstrated the sensitivity of UECT for urolith detection to be in the region of 95% (Patatas, *et al.,* 2012). Table 2.1 is a summary of research studies conducted that reported the detection rate of UECT KUB for urolithiasis.

Table 2.1 Detection rates of UECT KUB for urolith detection

Author	Sample size	Detection rate (%)
Smith, *et al.,* 1996	220	46
Dalrymple, *et al.,* 1998	417	43
Chen, *et al.,* 1999	100	28
Katz, *et al.,* 2000	1000	65
Greenwell, *et al.,* 2000	116	54
Tack *et al.* 2003	106	36
Kirpalani, *et al.,* 2005	234	65
Hoppe, *et al.,* 2006	1500	69
Chowdhury *et al.,* 2007	500	44
Kennish, et al., 2008	120	50
Patatas, et al., 2012	1357	47
Nadeem et al., 2012	1550	64

Studies concluded by Smith, *et al.,* (1996) Dalrymple *et al.,* (1998) Chen *et al.,* (1999) and Greenwell, *et al.,* (2000) reported sensitivity and specificity specifically for detecting urolithiasis with UECT KUB (Table 2.1). The aforementioned authors also investigated features such as suspicion of acute urolithiasis in adult males and females, supine scanning, sensitivity and specificity measurement, however; they did not mention any prone scanning, as it was not an objective of their specific studies.

Their findings showed sensitivity and specificity of well above 90% (Table 2.2) for UECT KUB for detecting urolithiasis during UECT KUB.

Table 2.2 Sensitivity and specificity for UECT KUB results from historic research

Author	Sensitivity (%)	Specificity (%)
Smith, *et al.,*1996	97	96
Dalrymple, *et al.,*1998	95	98
Chen*, et al.,*1999	96	99
Greenwell, *et al.,*2000	98	97

Various sites of urolith impaction have been noted in the literature. Table 2.3 indicates the most common sites of impaction from previous studies involving UECT KUB.

Table 2.3 Common site of urolith impaction

Author	Study sample size	Most common site of urolith impaction (%)
Lumerman *et al.,* 2001	17	Proximal ureter (17%)
El-Barky,*et al.,* 2013	300	Distal ureter (28%)
Chand, *et al.,* 2013	345	Intra-renal (68%)
Ahmad, *et al.,* 2015	5371	Intra-renal (73%)

On UECT KUB, almost all uroliths are of high attenuation, making identification easier (Chowdhury, *et al*., 2007). There are several well-recognized and validated signs of urolithiasis on UECT KUB (Chowdhury, *et al.,* 2007). These signs may be relevant in situations where no urolith can be seen because it is too small, has recently been passed, or is obscured due to partial volume averaging artefact. In addition to the detection of the radio-opaque uroliths, these signs include the presence of hydronephrosis, hydro ureter, asymmetric perinephric stranding, peri- ureteral stranding, renal enlargement, reduced renal attenuation, and the ‘‘tissue rim’’ sign (Cheng *et al.,* 2012). The ‘‘tissue rim’’ sign refers to the halo of soft tissue, corresponding to thickening or oedema of the ureteric wall, surrounding a urolith and differentiating it from other calcifications such as phleboliths (Chowdhury *et al.,* 2007). According to Patatas *et al*., (2012), the extent of perinephric oedema can allow a highly accurate prediction of the presence, anatomic level and severity of ureteral obstruction. Uroliths that are not radio-opaque are however still detectable on UECT KUB due to the high spatial resolution of CT (Mortele, *et al.,* 2003). In cases where uroliths are not visualized the diagnosis is made based on other signs of obstruction (Colistro *et al.,* 2002). When a UVJ urolith is encountered, the scanning protocol may vary. This variation may be brought on by uncertainty of whether a urolith is impacted at the UVJ or if it is located freely within the urinary bladder. Changing the patient position from supine to prone will facilitate the visualization of a urolith, that has passed, on the anterior aspect of the bladder (Colistro, *et al.,* 2002). Impacted uroliths will remain on the posterior aspect of the wall at the ureteral orifice (Cheng, *et al.,* 2012).

Levine, *et al.*, (1999) conducted a prospective study aimed at evaluating the DAE of the supine position compared to the prone position during UECT KUB for urolithiasis. During this research study 37 patients with acute flank pain underwent UECT KUB in the supine position; showing uroliths in the region of the UVJ. To determine the precise urolith location, limited rescans of the urinary bladder were performed with the patients in the prone position. The aforementioned authors calculated a sensitivity of 72%, a specificity of 100%, a positive predictive value of 100%, a negative predictive value of 50%, and an accuracy of 78% for prone UECT KUB in revealing uroliths impacted at the UVJ.

Levine, *et al.,* (1999) argued that if patients are imaged in the supine position only, UECT KUB could not reliably distinguish uroliths impacted at the UVJ from uroliths that have already passed into the bladder. Levine, Neitlich and Smith, (1999) believe that a prone rescan of the urinary bladder could be used to make this distinction.

Another more recent study by Meissnitzer *et al.,* (2017) aimed to similarly evaluate the DAE of prone UECT KUB compared to supine. Consecutively performed unenhanced CTKUB scans in patients with suspected urolithiasis were retrospectively analyzed in 150 patients in supine and another 150 patients in prone position from the outset. Two radiologists reviewed the images. Uroliths were diagnosed in 67% of subjects. Meissnitzer *et al.,* (2017) found in the supine scanning group, there were only 16 cases in which the location of the uroliths was confirmed. In contrast, in the prone imaging group, the location of 37 uroliths was confirmed. The authors agreed with Levine *et al.,* (1999) that prone scanning is superior to supine scanning for the detection of uroliths at the IVJ and suggested the patient be scanned in the prone position from the outset.

2.3.6.3 UECT KUB in detecting other pathologies

UECT KUB can reveal most renal abnormalities such as congenital anomalies, infections and neoplasms that may mean more severe consequences than urolithiasis (Mallin *et al.,* 2015). Flank pain is a profound symptom of urolithiasis. This important symptom may also be observed in much other abdominal and pelvic pathology (Jeong *et al.,* 2000). Since the autonomic nervous system transmits pain stimulus from nearby visceral organs via pain fibres shared with the urinary tract, urolithiasis may be misdiagnosed on clinical evaluation alone (Jeong *et al.,* 2000). Thus, CT remains an important aid to the clinician. The usefulness of UECT KUB includes, but is not limited to, the evaluation of renal masses, urolithiasis, genitourinary trauma and renal infection (Miller & Lingeman, 2007). With UECT KUB, detailed anatomical images of the entire abdomen and pelvis enable radiologists to evaluate other potential causes of the patient's symptoms if urolithiasis is excluded (Chen, *et al.,* 1999). UECT KUB studies have shown usefulness in detecting other pathologies that might mimic urolithiasis as indicated in table 2.4

Table 2.4 Non-urolithiasis pathology detection rate

Author	Sample size	Non-urolithiasis pathology detection rate (%)
Lane *et al.,* (1997)	109	22% (n=24)
Chen *et al., (*1999)	100	45% (n=45)
Katz, *et al.,* (2000)	1000	10% (n=101)
Greenwell *et al.,* (2000)	116	6% (n=7)
Christopher *et al.,* (2002)	101	20% (n=20)
Chowdhury *et al.,* (2007)	500	12% (n=59)
Patatas *et al.,* (2012)	1357	10% (n=136)
Smith, *et al.,* (2013)	292	10% (n=31)

Research studies referred to in Table 2.4 were based on evaluation of whether there had been an increase in the usage of UECT KUB at departments and evaluation of the referral patterns of clinicians working in the emergency department. The referral patterns were correlated against patient symptoms and final diagnosis. Also, these authors (refer Table 2.4) documented the types of pathology diagnosed, which showed that the detection rate for non-urolithiasis pathology ranged from 6%- 45%. The authors further concluded that there was no over-usage of UECT KUB. Thus, no deterioration in the diagnostic thinking efficacy was noted.

Various other pathological conditions have been observed in patients suspected of having urolithiasis at emergency departments. Gynaecologic conditions represent the most common non-urolith findings at UECT KUB followed by gastrointestinal conditions such as appendicitis and diverticulitis (Doria, *et al.,* 2006). Hepatobiliary abnormalities detected with UECT KUB are usually related to cholelithiasis. Impacted choleliths often mimic renal colic (Bove, *et al.,* 1998; Rucker *et al.,* 2004). In addition, cholecystitis may also mimic symptoms of urolithiasis at clinical examination and can be detected on CT scans obtained with a urolithiasis protocol (Dalrymple, *et al.,* 2007).

Vascular diseases represent the most difficult category of disease to diagnose using UECT KUB, and these are potentially the most life-threatening (Suzuki, 1996). The clinical findings of acute aortic and splanchnic arterial conditions as well as venous conditions may overlap with those of renal colic (Mehard, *et al.,* 1994; Acheson, *et al.,* 1998).

The clinical presentation of musculoskeletal pain is commonly mistaken for renal colic in the emergency department because of its non-specific nature. Lower mechanical back pain is a common example of a symptom mistaken for renal colic (Katz, *et al.,* 2000; Colistro, *et al.,* 2002). The symptoms of focal intra-peritoneal fatty infarctions may also be confused with urolithiasis; their detection on the UECT KUB examination depends on careful inspection of the fat surrounding the colon (van Breda Vriesman, *et al.,* 1999).

2.3.6.4 CT Urography (CTU) techniques

The following section aims to highlight current and future trends from the literature of CT imaging protocols for suspected acute urolithiasis. The goal of CTKUB protocols is to demonstrate fully distended and opacified collecting systems, ureters and urinary bladder for adequate evaluation. Multiple techniques have been reported to optimize urinary tract visualization and enhance urinary tract assessment (Weatherspoon *et al.,* 2017). However, Caoili, *et al*., (2005) and Kim, *et al.,* (2008) note that currently, no strict guidelines exist regarding the preferred method for optimal urinary tract opacification in UECT KUB. It is known that the urinary bladder shape changes as it fills up with urine and the distended urinary bladder may cause passed UVJ uroliths to fall in a more dependent position during supine scanning (Sutton, 2003).

Research conducted by Weatherspoon *et al.* (2017) observed that a maximally distended urinary bladder as preparation for UECT KUB for renal colic differs between radiology departments but the concept of hydration (oral/intravenous) to opacify collecting systems, ureters and urinary bladder is well articulated throughout the literature (Caoili *et al.,* 2005; Kim *et al.,* 2008; Weatherspoon *et al.,* 2017).

The UECT KUB scan conveys important information regarding calcification (uroliths among others) and extra-urinary masses or pathology as well as providing a baseline attenuation value for calculating enhancement in masses (Silverman *et al.,* 2009). With contrast media enhancement, the accuracy of CT to evaluate the KUB is significantly improved. CTU is generally defined as an investigation of the urinary tract with CT, before and after the contrast media administration. The scan range includes from the top of the kidneys to below the urinary bladder (Silverman *et al.,* 2009). All scans are performed on arrested respiration. Generally, four imaging phases for CTU exist namely the pre-contrast media scans, excretory phase, portal venous delayed phase (also termed the double bolus phase) and delayed excretory phase.
According to Silverman *et al.,* (2009) the four phases are as follows:

- The pre-contrast media phase is mainly used to scout for calcification.

- The excretory phase is performed by injecting contrast media and waiting 7-10 min and the patient is then scanned in the supine position.

- The double bolus phase is performed by injecting contrast media and waiting 7-10 min and then injecting another bolus of contrast media and waiting 65 seconds before scanning. During this phase, the first bolus is administered for opacification of the collecting systems (KUB). The second bolus is administered to opacify the portal venous system. This second phase is also termed the nephrographic phase and is mainly used to characterize renal masses.

The excretory phase is known to be the most profound stage of imaging during this procedure. Furthermore, Silverman *et al*., (2009), describe the excretory phase as ideal for intraluminal evaluation throughout the entire urinary tract. However, McTavish, *et al.,* (2002) describe the urinary tract as a complicated viscus system with variable degrees of distention and enhancement during contrast-enhanced CTKUB. The aforementioned authors investigated strategies for demonstrating the normal urinary tract and observed that the most distal parts prove most challenging during contrast-enhanced CTKUB. Some imaging centres make use of additional excretory phase scans that demonstrate a more distended and opacified distal urinary tract. This however does come at the price of higher radiation exposure factors (McTavish *et al.,* 2002). Furthermore, McNicholas, *et al.,* (1998); Chow and Sommer, (2001); Caoili, *et al.,* (2001) and Heneghan, *et al.,* (2001) agree that the use of a compression device to the distal urinary tract also facilitates better distention and opacification due to the distal region being flushed with contrast media after the release of compression.

2.3.6.5 Limitations of UECT KUB for acute urolithiasis

Many challenges may occur in the identification of uroliths with UECT KUB (Cheng, *et al.,* 2012). Soft tissue uroliths such as pure matrix urolith and urolith encountered in patients on ARV treatment are known to be challenging and are often missed with UECT KUB due to their soft tissue attenuation of between 15–30 Hounsfield units (HU) (Ahmed *et al.,* 2010).

Other challenges relate to calcifications that simulate uroliths. Within the kidney, vascular and dystrophic calcifications may mimic uroliths. Ring-like or linear calcification usually suggests a vascular cause as noted by Cheng *et al.,* (2012). Calcifications of the iliac vessels may be particularly difficult to differentiate from adjacent ureteric uroliths, however, by scrolling through consecutive images and following the ureters enables differentiation of ureteric from vascular calcification. While calcifications are responsible for most challenges in the diagnosis of urolithiasis on UECT KUB, there are several other potential challenges such as conditions that may mimic hydronephrosis (Patatas, *et al.,* 2012). This challenge can be overcome by scanning on a full urinary bladder, which helps to identify the UVJ and lifts overlying small bowel making interpretation easier. Incomplete scan ranges can also be challenging. Images should be acquired from the top of the kidneys to the lower border of the pubic symphysis (Colistro *et al.,* 2002). It is essential to include adequate anatomy that demonstrates the entire urinary tract in female patients because uroliths may be present in either the inferior part of the bladder or in a urethral diverticulum (Colistro et al*.,* 2002)

Multiphase contrast-enhanced CTKUB techniques prove more valuable for diagnosing urolithiasis and other pathologies. However, this comes at the cost of higher radiation doses to the patient as well as the risk of contrast-induced reactions and related injuries (Colistro *et al.,* 2002).In the acute setting, it is essential to consider a fast and effective imaging pathway such as UECT KUB. The next section will discuss treatment options for urolithiasis.

2.4 Treatment options for urolithiasis

Intervention rates for urolithiasis depend on the probability of spontaneous passage, which in turn may be predicted by urolith chemistry, size, location, symptoms, presence of backpressure changes and infection status (Türk *et al.,* 2014). A patient at risk for a urolith-related emergency often warrants hospital admission and subsequent urology consultation (Wang, 2016). Pain relief and intravenous (IV) hydration is frequently the first line of treatment for urolithiasis. In cases of obstructing uroliths, the urinary tract should be decompressed as soon as possible (Wang, 2016). Smaller and more distally located ureteral uroliths are more likely to pass spontaneously. About 95% of uroliths smaller than 5 mm were reported to pass spontaneously within a few weeks, and therefore are mostly treated conservatively (Gervaise *et al.,* 2016). However, another researcher observed this to be true for uroliths < 4mm (Dalla Palma *et al.,* 2001). On the other hand, Gervaise *et al.,* (2016) highlight the importance of smaller uroliths that do not pass spontaneously. Urolith passage may be delayed by infection, swelling and various other physiological changes within the urinary tract. This results in more frequent and severe pain and urgency that may warrant intervention even in cases of small uroliths (Gervaise *et al.,* 2016).

Coll *et al.,* (2002) studied the spontaneous urolith passage rate and found that measurements of urolith size have a nearly linear relationship with the frequency of spontaneous passage and intervention rates. They showed that uroliths measuring ≤4 mm will usually pass spontaneously (frequency of spontaneous passage = 78%); uroliths measuring ≥5–7 mm frequently pass spontaneously (frequency of spontaneous passage = 60%); and uroliths measuring >8 mm usually will not pass spontaneously (frequency of spontaneous passage = 39%) and warrants intervention. In this study by Coll *et al.,* (2002), no uroliths >10 mm passed spontaneously. Similarly, Jendeberg *et al.,* (2018) included research on passage rates of uroliths and demonstrated a high passage rate (98%, n=312 out of 392) for uroliths <5mm.

Urologists typically offer uretero-renoscopy (URS) or Extracorporeal Shock Wave Lithotripsy (ESWL) to patients with retained uroliths and persistent symptoms (Türk *et al.,* 2014). An investigation by Türk *et al.,* (2014) noted that patients are either managed conservatively if uroliths are smaller than 5mm and more distally located as opposed to endoscopically in cases of larger more persistent uroliths. The spontaneous passage rate is inversely proportional to urolith size (Masarani & Dinneen, 2007). Patients with urolithiasis and no indications for urgent intervention can be discharged with a plan of observation for spontaneous urolith passage (Türk *et al.,* 2014). Pain relief is discussed in the next section as the first line of treatment for urolithiasis.

2.4.1 Pain relief

Patients with acute urolithiasis are often offered an analgesic after exclusion of acute appendicitis and or acute surgical abdomen (Türk *et al.,* 2014). The use of non-steroidal anti-inflammatory drugs (NSAID) proves a more effective analgesic method compared to opioids during acute urolith episodes (Ebell, 2004). Holdgate and Pollock, (2004) concur and add that opioids, particularly pethidine, are known to result in a high rate of vomiting compared to NSAIDs, and the likelihood of further analgesia being needed is greater. If an opioid is used, it is recommended that pethidine is not used (Holdgate & Pollock, 2004). NSAIDs combined with alpha-blockers may decrease recurrent attacks of pain by relaxing the smooth fibres of the ureter to facilitate painless passage of any obstructive uroliths (Türk *et al.,* 2014). If analgesia cannot be achieved medically, drainage, using stenting or percutaneous nephrostomy or stone removal, should be performed.

2.4.2 Drainage and removal of uroliths

Indications for drainage of the urinary system and or urolith removal often include symptomatic or complicated/ lodged ureteral urolith as first-line treatment or if analgesia cannot be achieved medically. Urgent drainage of an obstructed urinary tract is usually achieved through either endoscopic insertion of a ureteral catheter/stent or percutaneous nephrostomy tube (PCN) (Türk *et al.,* 2014). Abou-Elela, (2017) reported that the decision of whether to place or omit a nephrostomy tube following urolith removal by percutaneous nephrolithotomy (PCNL) procedure is determined by the following parameters:

- Suspicion of residual urolith
- Possibility of a second procedure
- Significant bleeding
- Mucosal injury or perforation
- Ureteral obstruction
- Infected urolith and possibility of persistent infection
- Bleeding diathesis
- Premeditated chemo lysis.

Small-calibre nephrostomies have the advantages of less postoperative pain. When both a nephrostomy tube and a ureteral stent are omitted, the procedure is known as tubeless PCNL (Abou-Elela, 2017). In uncomplicated cases, tubeless or tubeless PCNL procedures provide a safe alternative with a shorter hospital stay (Abou-Elela, 2017). No statistically significant variation was reported in the efficacy of nephrostomy and retrograde stenting for primary treatment of infected urolithiasis in most research studies as reported during a systematic literature review by Türk *et al.,* (2014:).The aforementioned authors also noted during their review that definitive urolith removal must be postponed until the infection subsides after a full course of antibiotics. Furthermore, ureteral stent placements decrease the risk of recurrent pain and backpressure but do not improve urolith free rate, reduce the formation of impacted urolith fragments or infective complications as noted by Türk *et al.,* (2014).

2.4.2.1 Intra-corporeal urolith disintegration (lithotripsy)

Laser lithotripsy is the gold standard during URS, miniature PCNL and flexible endoscopes (Türk *et al.,* 2014). Studies comparing different systems of lithotripsy reported that with laser lithotripsy, the urolith migration rate is significantly less as compared to pneumatic lithotripsy and electrohydraulic lithotripsy (EHL). EHL is highly effective but may cause collateral damage according to Türk *et al.,* (2014).

2.4.2.2 Extracorporeal shock wave lithotripsy (ESWL)

The introduction of ESWL in the early 1980s revolutionized the treatment of nephrolithiasis (Miller & Lingeman, 2007). The fragmentation of uroliths with an extracorporeal shock wave lithotripter is known as extracorporeal shock wave lithotripsy (ESWL) (Abou-Elela, 2017). Patient habitus, urolith size, location (ureteral, pelvic or calyceal) and composition (hardness), operator of lithotripter and efficacy of the lithotripter are known factors that influence the efficacy of ESWL. ESWL sessions have high efficacy and can be repeated after 24 hours for persistent ureteral uroliths. If ESWL is unsuccessful for example in the case of more persistent uroliths, it may have to be treated with more invasive methods like PCNL (Abou-Elela, 2017).

2.4.2.3 Percutaneous nephrolithotomy (PCNL)

With the design of a wide range of rigid, semi-rigid and flexible urologic endoscopes, PCNL has become a common treatment for persistent and large diameter uroliths. PCNL is currently the gold standard procedure for large urolith (Türk *et al.,* 2014). Varieties of instruments are available and the use thereof is entirely based on the surgeon (Abou-Elela, 2017). The diameter of the standard access tracts is 24–30 French (F). In a review by Abou-Elela, (2017) the use of small pediatric access sheaths (18 French) in adults was highlighted. The therapeutic efficacy (TPE) was then compared to that of standard-sized sheaths PCNL. The same efficacy rates were noted, by Abou-Elela, (2017), between the two size options. However, less bleeding complications but longer theatre times were noted for pediatric sheaths.

Figure 2.1 is a visual representation of the characteristic patient management journey regarding acute urolithiasis as reported by Turk *et al.,* (2014). Urolith size together with symptom severity affects the treatment path once the location of the urolith has been established. The next section will discuss the approach to evaluating the efficacy levels of an imaging system.

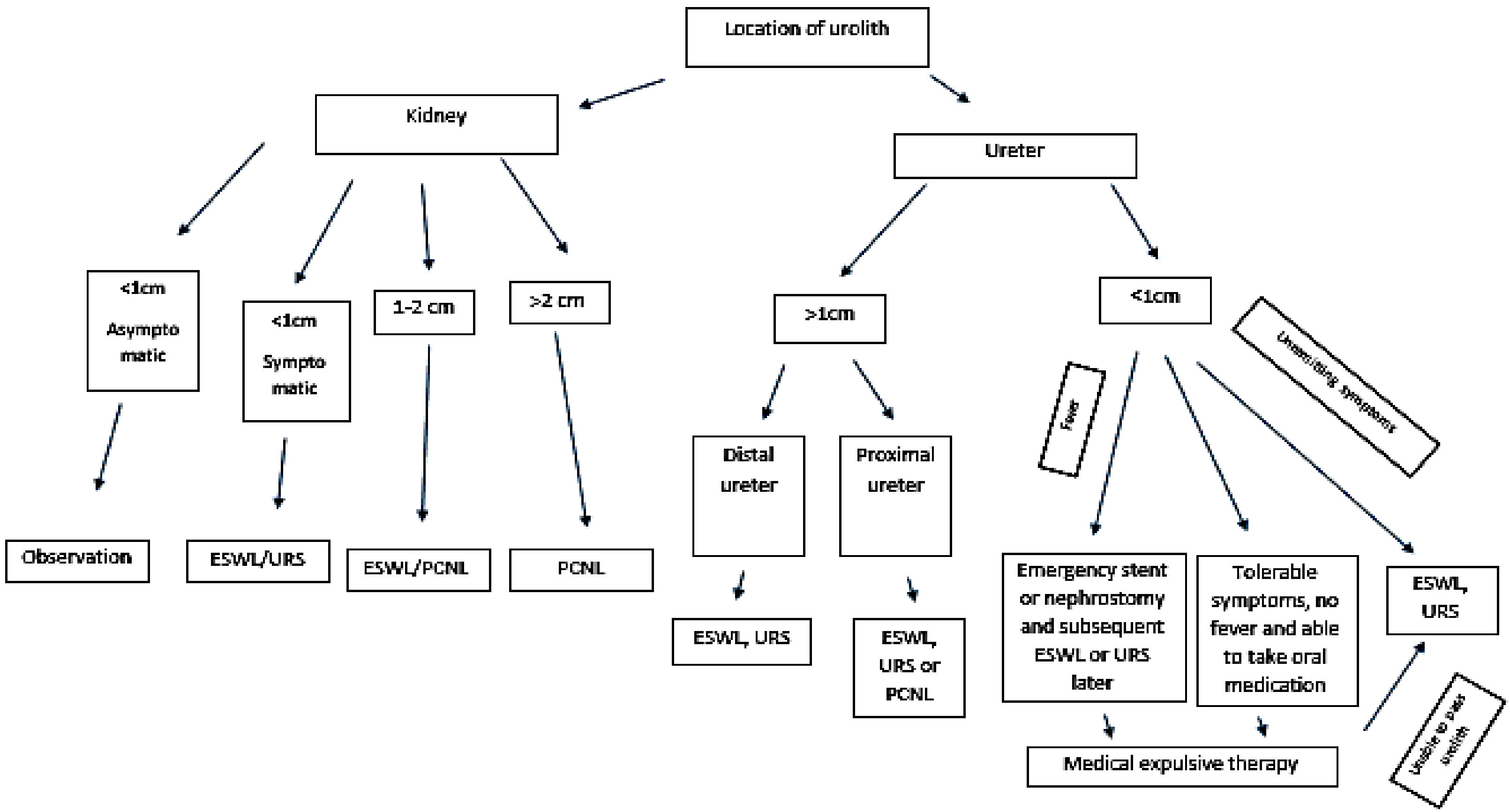

Figure 2.1 Patient journey map for acute urolithiasis

(Adapted from Turk *et al. 2014)*

2.5 Evaluation of a radiological imaging system

Diagnostic tests have the potential to create value along three dimensions namely medical value (a diagnostic test's ability to inform clinical treatment); planning value (a diagnostic test's ability to inform patients' choices about reproduction, work, retirement, long-term health and financial planning) and psychic value (how diagnostic tests can directly change patients' sense of satisfaction) (Gazelle *et al.,* 2011). Evaluation of the efficacy of medical imaging systems can take many forms, from the purely technical e.g., patient dose measurement to the increasingly complex e.g., determining whether a new imaging method saves lives and benefits society. Fryback and Thornbury (2008), use a hierarchy to evaluate certain levels of efficacy to establish if outcomes are efficacious and of benefit to the patient.

Since the development of CT in the late 20th century the success of this, radiological imaging modality is widely celebrated. However, as with all diagnostic tests, the use of CT in practice raises important questions concerning when, how and where it should be used (Krupinsky & Jiang, 2008). According to Krupinsky & and Jiang (2008), all aspects of the entire imaging cycle should be carefully evaluated to justify any scenario where CT scans are requested.

The imaging cycle consists of hardware, imaging technique, image archiving system and interpretation. Each of these steps has measurable parameters that answer the clinical question. Thus determining the efficacy rate of each step that contributes to the overall efficiency of the cycle or imaging system (Krupinsky & Jiang, 2008).

Fryback and Thornbury (1991) proposed a hierarchy of six levels of diagnostic efficacy, which can be used as a guideline for the evaluation of various medical imaging cycles (Table 2.5). The six levels of efficacy the authors proposed are as follows:

- Technical efficacy (TE)
- Diagnostic accuracy efficacy (DAE)
- Diagnostic thinking efficacy (DTE)
- Therapeutic efficacy (TPE)
- Patient outcome efficacy (POE)
- Societal efficacy (SE)

Fryback and Thornbury (1991) as the benefit to individuals from a system or test under ideal conditions of use define efficacy, in this context. The six levels of diagnostic efficacy by Fryback and Thornbury (1991) is explained in table 2.5

Table 2.5 Six levels of diagnostic efficacy

Levels of diagnostic efficacy	Definition	Commonly measured parameters
Technical efficacy (TE)	How accurately and precisely it measures what is to be measured.	Physical parameters e.g., dose
Diagnostic accuracy efficacy (DAE)	How well or accurately a system or test predicts presence/absence or extent/magnitude of a disease or health condition.	Sensitivity, specificity, positive/negative predictive value, accuracy
Diagnostic thinking efficacy (DTE)	Impact of diagnostic test results on clinician's estimate of the probability that a patient suffers from a disease or health condition	Changes in diagnosis, prognostic assessment, etc., before and after a diagnostic test
Therapeutic efficacy (TPE)	Whether or how much the system or test changes patient's course of treatment/care.	Changes in treatment regimen—type of treatment, dose etc.
Patient outcome efficacy (POE)	Degree to which patient's health/condition improves.	Survival rates, quality of life
Societal efficacy (SE)	Impact of the system/test on society as a whole.	Cost-benefit analyses, number of lives saved

Adapted from Fryback and Thornbury (1991)

The current study focused on Diagnostic accuracy efficacy (DAE), Diagnostic thinking efficacy (DTE) and Therapeutic efficacy (TPE). Due to the retrospective nature of this study, the evaluation of technical efficacy (TE), patient outcome efficacy (POE) and societal efficacy (SE) were not evaluated. These aspects were also not the objectives of the research study.

Imaging plays an important role in the diagnosis of acute urolithiasis as well as its pre-treatment planning and post-treatment follow-up. Appropriate imaging techniques are essential to provide the correct clinical care for the affected population. Several research studies have been conducted that adds value to the body of knowledge of the various treatment options for acute urolithiasis and the clinical relevant imaging findings (Fulgham, *et al.,* 2013, Abou-Elela, 2017). Research regarding acute urolithiasis imaging findings plays an important role in assisting image interpretation and further patient management (Cheng, *et al.,* 2012).

The next chapter will discuss the methodology that was followed to evaluate three levels of diagnostic efficacy of the UECT KUB examination protocol at the research site.

CHAPTER THREE: RESEARCH METHODOLOGY

When urolithiasis is suspected, it is important to determine the presence, location and size of uroliths as these factors influence patient management. The main purpose of this study was to investigate urolithiasis detection rates, non-urolith related pathology diagnosed during UECT KUB and factors possibly influencing intervention rates involved with urolithiasis. The efficacy of the UECT KUB examination protocol used at the research site was investigated on three of the seven levels of diagnostic efficacy namely diagnostic accuracy efficacy (DAE), diagnostic thinking efficacy (DTE) and therapeutic efficacy (TPE) as mentioned in section 2.4.

3.1 Research study design

A retrospective, cross-sectional design was used by analysing patients' records to evaluate the diagnostic efficacy of the UECT KUB examination protocol, for suspected acute urolithiasis, at the research site. This research study consisted of five stages:

- The first stage identified on the PACS all UECT KUB studies for suspected acute urolithiasis during the period 01 January 2010 to 31 December 2017
- The second stage identified on the PACS all records where UVJ uroliths were visualised. This enabled the researcher to gather descriptive data such as gender, protocol information such as projections done (i.e. supine CT imaging only or supine and prone CT imaging), and examination findings such as urolith size, lodged uroliths, passed uroliths
- The third stage aimed at identifying all records where other uroliths were diagnosed at other locations in the urinary tract. Gender, urolith amount and urolith size were also recorded.
- The fourth stage aimed at identifying records where no cause could be found for patients' symptoms and were diagnosed as normal studies. Gender and symptoms were also recorded.
- The fifth stage aimed at identifying all records where other pathologies was diagnosed other than urolithiasis. Gender, symptoms and the type of pathology diagnosed were also recorded.

Table 3.1 is a summary of the three levels of diagnostic efficacy used to evaluate efficacy in this context.

Table 3.1 Three levels used to evaluate the diagnostic efficacy

Level	Description	Method of measurement
Diagnostic accuracy efficacy (DAE)	How well or accurately a system or test predicts presence/absence or extent/magnitude of a disease or health condition.	Sensitivity, specificity, positive/negative predictive value, accuracy
Diagnostic thinking efficacy (DTE)	Impact of diagnostic test results on clinician's estimate of the probability that a patient suffers from a disease or health condition	Changes in diagnosis, prognostic assessment, etc., before and after a diagnostic test
Therapeutic efficacy (TPE)	Whether or how much the system or test changes patients' course of treatment/care.	Changes in treatment regimen—type of treatment, dose etc.

3.2 Research aim and objectives

The research study aimed to evaluate three levels of diagnostic efficacy of the current UECT KUB protocol performed at the research site.

The objectives of this research study were:

- To investigate the detection rate of urolithiasis as a parameter of diagnostic accuracy efficacy (DAE).
- To evaluate the detection rate of non-urology pathology as a parameter of diagnostic thinking efficacy (DTE).
- To determine the contribution of UECT to the patient management process as a parameter of therapeutic efficacy (TPE).

For this research study, the following are hypothesised:

H0 – The UECT KUB protocol for detecting acute urolithiasis is optimal with regard to DAE, DTE and TPE.

H1 – The UECT KUB protocol for detecting acute urolithiasis is not optimal with regard to DAE, DTE and TPE.

3.3 Research study site

The research site was a private radiology department situated in the Cape Metropole. The UECT KUB examinations were performed on a Siemens Emotion 16, a 16-detector row unit (Siemens Medical Solutions, Erlangen Germany, 2000). The vendor advised the following parameters (Table 3.2) for UECT KUB examinations performed with this equipment.

Table 3.2 Parameters used at the research site for UECT KUB examinations

Parameter	Value
mAs	104
kV	130
Pitch	1.4
Acquisition slice thickness	5 mm
Scan time	24 seconds
Rotation time	0.6 seconds
Prescan delay	4 seconds
Scan direction	Cranio-caudal

The research site employed a PACS by AGFA (Enterprise Imaging) for all imaging studies.

Figure 3.1 is a flow chart illustrating the UECT KUB examination protocol for patients referred with suspected acute urolithiasis at the research site.

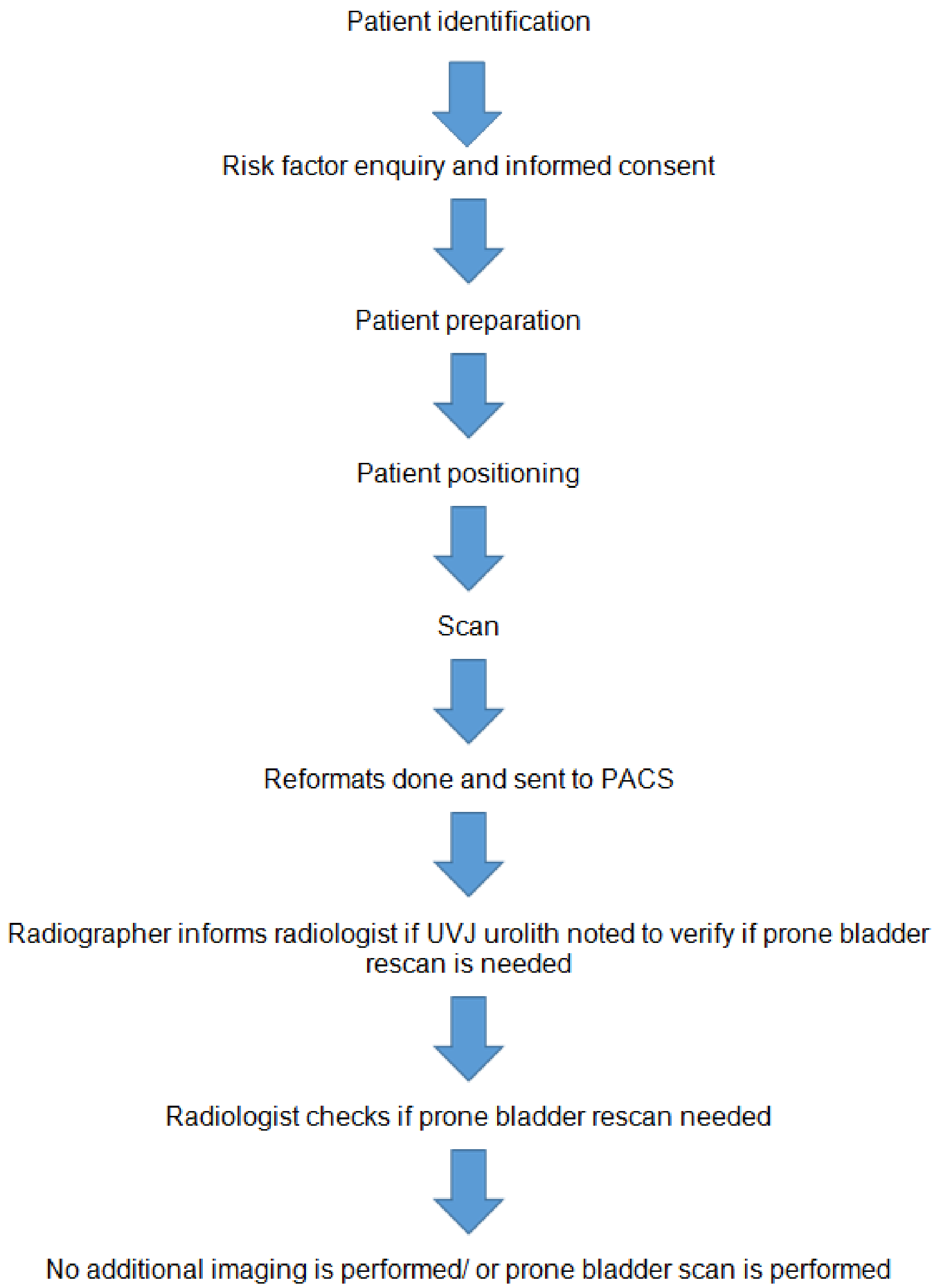

Figure 3.1 Flow diagram of examination protocol for patients referred for UECT KUB

3.4 Sampling Method and sample population

Due to the retrospective nature of this study, the researcher employed a convenience sampling method. The information was readily available on the PACS at the research site. The data, in the form of radiological reports, were collected from the PACS. For this study, 766 CTKUB examinations were identified from the PACS.

3.5 Inclusion Criteria

Data of patients, who had been referred for UECT KUB for suspected urolithiasis during the specific period 01 January 2010 to 31 December 2017 were included in the study. Data of both male and female patients between the ages of 18 and 75 were included This study focused only on acute cases where referral patterns for UECT KUB and the efficacy of the imaging examination, in the acute setting, could be evaluated.

3.6 Exclusion Criteria

Data of patients referred for suspected urolithiasis outside the period from 01 January 2010 to 31 December 2017 were excluded. Data of patients younger than 18 years were excluded. Children were excluded, as were the elderly over 75 years of age because different imaging and treatment pathways are followed for urolithiasis in these age groups. All patient records that indicated more than one CTKUB examination were also excluded to ensure that follow up CT KUB examinations were not included as part of the data collection.

3.7 Data Collection

PACS are now ubiquitous components of radiology. For routine applications, PACS provide a robust, secure, and easy to use interface to clinical imaging data (Doran *et al.,* 2012). The researcher employed the PACS for data collection. This technology not only is economical (film-less department) but also convenient to access multiple modalities (conventional/general radiography, CT, MR, ultrasound etc.) simultaneously at multiple locations within hospitals (Doran *et al.,* 2012). This system allows for rapid transfer, retrieval and communication of patient data. Doran *et al.,* 2012 note that the major limitation of PACS is the quality of images, which may be compromised by the resolution of display monitors at different locations. Therefore the researcher observed radiological reports together with images during data collections. Also, any technical failure and improper back-up storage may hinder transfer, retrieval and communication of patient data. No data losses have been reported between 1 January 2010 and 31 December 2017 at the radiology practice involved at the study site. The next section will discuss in detail all aspects of the data collection process for this research study.

3.7.1 Data collection steps

The flowchart (Figure 3.2) below gives an overview of the data collection steps conducted during this research study.

Figure 3.2 Flow diagram of the data collection process.

3.7.1.1 Filtered PACS search

With permission from the managing committee at the research site and ethical approval from CPUT, the researcher accessed PACS at the study site to obtain data by using search filters. Data stored in the PACS are organized to permit efficient retrieval. Unique data object identifiers (UID) permits partitioning of elements in data. The database can map user retrieval requests, expressed in terms of relevant descriptive elements, into UIDs of specific data objects (Doran *et al.,* 2012). This is also referred to as the PACS filter. Table 3.3 illustrates relevant descriptive elements used to identify data for inclusion in this study.

Table 3.3 PACS filter parameters for data collection

Study date from	Is	01/01/2010
Study date to	Is	31/12/2017
Modality	Is	CT
Procedure name	Is	Renal Tract for stone
Study site identification number	Is	(omitted)
Patient age at acquisition.	between	18 and 75 years

3.7.1.2 Record grouping

Table 3.4 illustrates how the researcher systematically checked the characteristics of each patient record under inspection and the action taken when identified on PACS. The researcher used the radiological report comment to establish if urolithiasis were diagnosed. If urolithiasis were diagnosed the researcher documented the number, size and location(s) thereof for any further evaluation concerning the levels of efficacy (refer to Table 3.2). Records, where UVJ uroliths were visualized, were documented as a protocol variation. This protocol variation was documented for further investigation with regard to why it occurred in some instances and not in others. If no urolithiasis was detected the researcher checked the report for any other pathologies and documented this on the data collection sheet (Refer Appendix C). In cases where no pathology was recorded this was also documented in the collection sheet.

Table 3.4 Data inspection performed by the researcher

Characteristic checked on PACS	Action taken
Urolithiasis	If urolithiasis was diagnosed, the researcher documented: • Number of uroliths present • Urolith size • Urolith location If no urolithiasis was diagnosed, the researcher documented: • Non-urolithiasis pathology detected or no appreciable disease
Prone imaging performed	Documented as either yes or no
Intervention planned	Type of intervention was documented

3.7.1.3 Data capturing and coding

During the review of the 766 records, the researcher started with the earliest date, which was 01 January 2010 to the latest date of 31 December 2017. Common information captured on all four data collection sheets were the patient identification number and gender. The next section discusses the other information captured on each data collection sheet.

3.7.1.3.1 Urolithiasis diagnosed

Records, where urolithiasis was diagnosed, were recorded by entering the following information to investigate diagnostic accuracy efficacy (DAE):

- Identification number
- Gender
- Urolith location
- Urolith amount
- Urolith size
- Whether intervention was planned or performed

An identification number is a number allocated to each patient at the research site. This number was important to identify multiple UECT KUB scans on the same patient to exclude any follow-up cases. Only acute scenarios, with no previous urolith events, were included. Gender was recorded to investigate male to female ratio referred for UECT KUB at the study site. The urolith location, size and amount were recorded to observe if any correlation exists between a urolith event and other variables. Instances where UVJ uroliths were visualized, it was also recorded from the radiological report whether a prone rescan of the bladder was done to determine if a urolith was located intra-vesical or impacted at the UVJ. Furthermore, it was recorded whether an intervention was required in each case for correlation with other variables to determine if this protocol variation affected the treatment path of patients. The next section discusses the examinations where no cause for the patient's symptoms could be found.

3.7.1.3.2 No appreciable disease

During the evaluation of records for this research study, the symptoms of patients who did not show any pathology were recorded from request letters. Records, where no pathology was demonstrated were recorded by entering the following information.

- Identification number
- Gender
- Symptoms from reports

This section interlinks with the previous and the following section in that it aims to evaluate the impact of UECT KUB results on clinician's estimate of the probability that a patient suffers from acute urolithiasis or other pathologies.

3.7.1.3.3 Other pathologies detected during UECT KUB.

During the evaluation of records for this research study, the symptoms of patients who were diagnosed with pathology other than urolithiasis were retrospectively categorized from request letters. Records, where other pathologieswas demonstrated were recorded by entering the following information on the data collection sheet.

- Identification number
- Gender

- Symptoms from reports
- Pathology diagnosed

All clinical symptoms on reports were documented to evaluate if any correlation exists between the symptoms and predictability of diagnosed pathology.

3.8 Statistical analysis

A data extraction sheet was created with Microsoft Excel 2013 (Appendix C). All data were loaded from Microsoft Excel into NCSS 2019 Statistical Software (2019). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/ncss, Frequency analysis was done from data entered on the data extraction sheet. Highest and lowest frequencies of variables were analyzed.

To determine DAE, the frequency of urolithiasis detected, locations of uroliths and sizes of uroliths were explored by considering supine and prone positions during UECT KUB. The frequency of non-urolithiasis related pathology detected and types of pathology encountered during UECT KUB for suspected acute urolithiasis were analyzed as a parameter of DTE. Frequency analysis was performed on data that showed urological intervention (TPE) after UECT KUB for suspected acute urolithiasis. Chapter 4 provides a detailed discussion of the research results.

3.9 Ethical considerations

Permission to conduct this research study was obtained from the managing committee of the autonomous private radiology practice in the Cape Metro Pole (refer to appendix A). After permission to conduct this research study was obtained from the study site, permission was obtained from the Research Ethics Committee of the Faculty of Health and Wellness Sciences of the Cape Peninsula University of Technology (CPUT) (refer to appendix B).

All indicators that may compromise the confidentiality of the radiology department and patients were removed from data that was collected. During data collection no patient information was removed from the research site, data were stored on an encrypted hard drive and kept in the departmental safe with only the researcher and head of the department having access to it.

The ethical principles of the Declaration of Helsinki were adhered to during this research study in the following ways:

- No patients were involved in the research study therefore no patient consent was required and no patient was harmed or coerced to participate, or was disadvantaged or directly benefited from this study.
- Patient information (age, gender and date of birth) displayed on digital records were kept confidential at all times. All records were anonymised after saving it on the researcher's external hard drive to protect the identity of all cases included.
- The researcher discussed the research study with the assigned supervisors before embarking on the research.
- The data collection only commenced once the Research Ethics Committee of CPUT had granted ethical approval.

3.10 Reliability and Validity

The methodology of this research study was centred on retrospective data collection from the PACS. The PACS made instant data retrieval possible through a search filter. The reliability of the PACS to retrieve data according to the search filter is directly linked to administrative processes involved. Administrative processes in the radiology department group data together on PACS. When a patient is entered into the radiology information system the personal patient data together with imaging data is duplicated onto PACS.

To ensure that data collected from PACS are reliable and valid the researcher carefully delineated the inclusion and exclusion criteria applied on the PACS. However, data duplicated to the PACS were observed to be only as reliable and valid as the operator of the radiology information system and the PACS. Several entries on PACS had to be excluded due to administrative errors due to human error.

This chapter outlined the methodology applied for this research study. The next chapter outlines the results observed during this research study.

CHAPTER FOUR: RESULTS

The following section will present the results of this research study. The research study aimed to evaluate three levels of diagnostic efficacy of the current UECT KUB protocol applied at the research site for detecting suspected acute urolithiasis.

The research objectives of this research study were:

- To investigate the diagnostic accuracy of the UECT KUB protocol for detecting acute urolithiasis as a parameter of DAE
- To evaluate the detection rate of non-urology pathology as a parameter of diagnostic thinking efficacy (DTE)
- To investigate to what extent the results of the UECT KUB influenced patient management as a parameter of TPE

4.1 Sample characteristics

For this research study, 753 patient records were identified and reviewed. A total of 449 records that matched the inclusion criteria were analyzed. The male to female ratio of CT imaging procedures performed was 61% to 39% (274 males to 175 females). The overall mean age of the sample was 44 years (SD± 2.2). The mean age for females was 42 years (SD±13.24) and 58 years (SD±17.45) for males.

4.2 Uroliths detected after UECT KUB

This section presents the data for the detection of uroliths during UECT KUB as a parameter of DAE in the diagnosis of urolithiasis at the research site. All CT imaging procedures were performed in the supine position however 46 of the cases required additional prone CT imaging of the urinary bladder. This was highlighted by the protocol variation encountered for the UECT KUB protocol at the research site. Detection of UECT KUB for suspected acute urolithiasis was reviewed with regard to the number of uroliths, location and size of uroliths. UECT KUB demonstrated either the presence or the absence of urolithiasis in 449 cases reviewed. The total number of positive cases for urolithiasis was 35% (n=159). From the information in the radiology reports it was found that 87% of reports (n=144) noted only 1 urolith present and 15% of reports (n=18) noted multiple uroliths present (Table 4.1).

Table 4.1 **Number of uroliths detected.**

Urolith(s) detected	Number of cases
Single urolith	n=144
Multiple uroliths	n=18
Total	159

Urolithiasis was documented in various locations throughout the urinary tract. In some cases, urolithiasis was documented in more than one location in the same individual. Table 4.2 shows uroliths detected per location. The most common site of urolith detection was intrarenal (n=144, 24%) while the least common site of occurrence of a urolith was the urethra (n=2, 0.33%).

UVJ uroliths were visualised in 30% (n=133) of cases and prone scanning was performed in 35% (n=46) of the total cases where UVJ uroliths were suspected. Intra-vesical uroliths after prone scanning contributed 35 cases while 11 cases revealed lodged uroliths at the UVJ. It should be noted that all 11 cases that revealed lodged uroliths had a diameter ≥5mm. Previous research studies revealed that uroliths with a diameter of ≥5mm have a higher likelihood to become lodged along the ureters.

Table 4.2 Urolithiasis detected per location

Location of uroliths in the urinary tract	Number of uroliths detected per location(n)
Intra-renal	n=144
Uretero-vesical junction (UVJ)	n=133
Urinary bladder	n=110
Distal ureter	n=108
Proximal ureter	n=48
Mid-ureter	n=33
Pelvi-ureteric junction (PUJ)	n=16
Urethra	n=2
Total	n=594

Table 4.3 provides data regarding urolith size and amount. A total of 36% of uroliths with a maximum diameter of ≥5mm and 46% of uroliths (n=229) had a maximum diameter < 5mm. Records indicated 17% of uroliths (n=86) had unspecified measurement.

Table 4.3 Urolith size versus number of uroliths detected

Urolith size	Number of uroliths detected
≥5mm	n =181
< 5mm	n =229
Unspecified urolith measurement	n =86
Total	496

Diagnostic accuracy measurement was anticipated with regard to urolith amount, urolith location, and size of uroliths as a parameter of diagnostic accuracy efficacy (DAE). The next section will outline research results relating to the measurement of the clinical predictability of urolithiasis as a parameter of diagnostic thinking efficacy.

4.3 DTE of UECT KUB for suspected acute urolithiasis

Diagnostic thinking efficacy (DTE) was anticipated through measurement of the symptoms warranting requests for UECT KUB and detection of non-urolithiasis related pathology diagnosed rather than urolithiasis per se. The researcher also documented symptoms leading to suspicion of acute urolithiasis. From the sample, 16% of records (n=113) indicated non-urolithiasis related pathology.

4.3.1 Symptoms recorded from requests for UECT KUB for suspected acute urolithiasis

A variety of symptoms (Table 4.4) were recorded from referrals for UECT KUB for suspected acute urolithiasis at the research site. Flank pain (n=28, 25%), flank pain with hematuria (n=24, 21%) and renal colic (n=13, 11%) were the symptoms with the highest occurrence amongst patients diagnosed with non-urolithiasis related pathology.

Table 4.4 Symptom distribution and number of referrals for UECT KUB

Symptom distribution	n=number of referrals
Two weeks post-partum, hematuria	n=1
abdominal pain	n=6
Abdominal pain, dysuria	n=1
abdominal pain, hematuria	n=2
back pain	n=3
back pain, flank pain	n=1
back pain, peritonitis	n=1
epigastric pain	n=1
flank pain	n=28
fever, renal angle pain	n=1
flank and pelvic pain, hematuria	n=1
flank pain, nausea, hematuria	n=1
flank pain hematuria	n=24
flank tenderness	n=1
groin pain	n=2
hematuria	n=4
hematuria, nausea, vomiting	n=1
loin pain	n=2
loin pain, hematuria	n=2
lower abdominal pain, hematuria	n=2
lumbar pain, hematuria	n=1
no clinical details	n=1
pain	n=1
periumbilical pain	n=1
urinary tract infection	n=2
renal colic	n=13
renal colic, hematuria	n=5
severe urgency, hematuria	n=1
sharp abdominal pain	n=1
sub-pubic pain	n=1
Upper abdominal pain	n=1

4.3.2 Non-urolithiasis related pathology

A variety of non-urolithiasis related pathologies (Table 4.5) were detected with UECT KUB. The non-urolithiasis related pathology contributed 16% (n=113) of the sample. Gastrointestinal pathology accounted for the highest occurrence at 32% (n=37) with other urinary tract pathology following at 28% (n=32).

Table 4.5 Distribution of non-urolithiasis related pathology

Pathological finding	n=total
Gastrointestinal pathology	n=37 (32%)
Other Urinary tract pathology	n=32 (28%)
Reproductive system pathology	n=19 (17%)
Hepatobiliary pathology	n=12 (10%)
Musculoskeletal pathology	n=9 (8%)
Vascular pathology	n=4 (3%)
Total	**113**

The next section discusses to what extent the results of the UECT KUB influenced patient management as a parameter of therapeutic efficacy with regard to urolith characteristics.

4.4 TPE of UECT KUB of the supine and prone projections for suspected urolithiasis

Urologic intervention was indicated in 46% of cases (n=201) who were diagnosed with acute urolithiasis (Table 4.6). The highest intervention rate was documented for single uroliths in the distal ureter. All uroliths in this region that required intervention had a diameter of ≥ 5mm. The second highest intervention rate was documented in cases with multiple uroliths at multiple locations throughout the urinary tract at 27% (n=54).

Table 4.6 Urolith location by intervention rate

Urolith location	Intervention rate
Distal ureter	28%(n=57)
Multiple locations	27%(n=54)
Uretero-vesical junction	17%(n=36)
Intra-renal	13%(n=26)
Mid-ureter	7%(n=15)
Proximal ureter	4%(n=9)
Intra-vesical	1%(n=3)
Pelvi-ureteric junction	0.5%(n=1)
Total	**201**

The ability of UECT KUB to demonstrate the presence and extent of suspected urolithiasis was outlined in this section with 35% (n=159) of the sample diagnosed with urolithiasis. Observation was also made regarding the clinical predictability of urolithiasis as a parameter of diagnostic thinking efficacy where 16% of the sample (n=113) had non- urolithiasis pathology present. Therapeutic efficacy was measured by observation of factors influencing treatment after UECT KUB for suspected urolithiasis. The next chapter will discuss the interpretation of results, limitations of the research study will be discussed and recommendations will be suggested.

CHAPTER FIVE: DISCUSSION

This research study evaluated the current UECT KUB protocol applied at the research site for detecting suspected acute urolithiasis. Patient records were retrospectively analyzed with regard to three levels of efficacy namely diagnostic accuracy efficacy (DAE), diagnostic thinking efficacy (DTE) and therapeutic efficacy (TPE). This section discusses the findings of the DAE, DTE and TPE of UECT KUB for suspected acute urolithiasis. The strengths and limitations of the research study are also discussed and recommendations made for practice and areas of further research.

5.1 DAE of UECT KUB for suspected acute urolithiasis

UECT KUB allows an accurate diagnosis of urolithiasis. This study showed that UECT KUB can demonstrate the presence, location, amount and size of uroliths. However, in cases were uroliths were visualised in the UVJ region, the study site protocol varied. Prone scanning has been shown to yield 100% sensitivity and specificity for detecting uroliths at the UVJ (Levine, *et al.,* 1999). Special care must be taken to keep the radiation dose as low as reasonably achievable when rescanning. Prone rescanning of the bladder would save the radiographer time if performed from the outset. However, patients who are already in pain might not tolerate the prone position and the rest of the anatomy might be altered decreasing the detection rate of non-urolithiasis related pathology at UECT KUB for suspected acute urolith events. The results suggest that after a supine scan does not show if a urolith has passed into the urinary bladder, a prone rescan of the bladder may be performed. This is particularly valuable with uroliths ≥5mm as the size of the urolith influences patient management. In this research study, UECT KUB detected urolithiasis in 35% of cases reviewed (n=159/ 449). This finding is similar to results of previous studies compared by Chowdhury *et al.* (2007) (refer Table 5.1). Findings of the current study are similar to study findings conducted by others (Table 5.1) which showed a rate of 44% for urolithiasis (n=221) from a sample of 500 patient records.

Table 5.1 Comparison of positive urolithiasis diagnosis rates with historic research

Author	Study sample population	Positive diagnosis rate (%)
Smith, *et al.,* (1996)	220	46
Dalrymple, *et al.,* (1998)	417	43
Chen, *et al.,* (1999)	100	28
Katz, *et al.,* (2000)	1000	65
Greenwell, *et al.,* (2000)	116	54
Tack *et al.* (2003)	106	36
Kirpalani, *et al.,* (2005)	234	65
Hoppe, *et al.,* (2006)	1500	69
Chowdhury *et al.,* (2007)	500	44
Kennish, *et al.,* (2008)	120	50
Patatas, *et al.,(*2012)	1357	47
Nadeem *et al., (*2012)	1550	64
Current study	**449**	**35**

Adapted from (Chowdhury et al., 2007)

The majority of uroliths detected in the current study occurred intra-renal (n=144, 20%). This finding is in agreement with the study by Chand *et al.,* (2013) and Ahmad, *et al.,* (2015) that included both males and females and showed the majority of uroliths to be located intra-renal (Table 5.2). The uroliths in the proximal ureter were observed in 16% of the entire urolith burden during the current study. From the study sample, 11% of uroliths were demonstrated in the mid-ureteric region. The distal ureter demonstrated a urolith burden of 36%. Furthermore, in the current study, confirmed intravesical uroliths, that did not need a prone bladder rescan, amounted to 8% (n=37).

Table 5.2 Comparison of common sites of urolith location with historic research

Author	Study sample size	Most common site of urolith location
Lumerman *et al.,* (2001)	17	Proximal ureter (17%)
Chand, *et al.,* (2013)	345	Intra-renal (68%)
El-Barky,*et al.,* (2013)	300	Distal ureter (28%)
Ahmad, *et al.,* (2015)	5371	Intra-renal (73%)
Current study	**449**	**Intra-renal (20%)**

UECT KUB proved to be accurate in demonstrating the location, size and number of uroliths in the current study.

5.2 DTE of UECT KUB for suspected acute urolithiasis

UECT KUB, when flank pain is experienced, demonstrates increased utility with regard to the management of non-urolithiasis related pathology. When acute urolithiasis is suspected, the most important objective is to identify those patients who require urgent, and in some cases, emergency treatment, either for important alternative diagnoses (appendicitis, cholecystitis, ovarian torsion, etc.) or “urolith related emergencies” such as sepsis (Weatherspoon *et al*., 2017). The current study also showed UECT KUB is a valuable technique for examining patients with acute abdominal pain. When UECT KUB excludes urolithiasis, other pathologies can be demonstrated and referred for follow-up by appropriate specialities (Brisbane *et al.,* 2017). Various pathologies may manifest as acute flank pain and mimic urolithiasis. The ability to diagnose these conditions with UECT KUB, in addition to the speed and high accuracy in urolithiasis detection, has resulted in the universal acceptance of UECT KUB as the gold standard for urolithiasis detection (Smith, *et al.,* 2013). UECT KUB has shown a variety of other pathologies in 16% of records evaluated. This detection rate is similar to those found in other studies as indicated in table 5.3

Table 5.3 Detection rate of non-urolithiasis pathology with UECT KUB

Author	Sample population size	Non-urolithiasis related pathology detection rate (%);n=total cases
Lane *et al.,* (1997)	109	22% (n=24)
Chen *et al., (*1999)	100	45% (n=45)
Katz, *et al.,* (2000)	1000	10% (n=101)
Greenwell *et al.,* (2000)	116	6% (n=7)
Christopher *et al.,* (2002)	101	20% (n=20)
Chowdhury *et al.,* (2007)	500	12% (n=59)
Patatas *et al.,* (2012)	1357	10% (n=136)
Smith, *et al.,* (2013)	292	10% (n=31)
Current study	**449**	**16% (n=114)**

Other pathologies diagnosed by UECT KUB for suspected acute urolithiasis such, as diverticulitis, incarcerated hernia, appendicitis, and abdominal perforation required immediate medical attention. UECT KUB can facilitate a rapid diagnosis in cases that need immediate attention when suspected urolithiasis is excluded (Brisbane *et al.,* 2017). Preceding signs and symptoms, of non-urolithiasis related pathology presenting at the clinical examination may overlap with that of urolithiasis. However, UECT KUB is accurate in the detection of non-urolithiasis related pathology and patients could be referred for further specialised investigation or treatment (Weatherspoon *et al.,* 2017). This is similar to the findings in other studies (Table 5.3). UECT KUB for suspected acute urolithiasis has shown its usefulness in detecting other pathologies.

5.3 TPE of UECT KUB for suspected urolithiasis

Therapeutic efficacy (TPE) is about how the results of a test affect patient management and in this case, it was about the size of the urolith. Gervaise *et al.,* (2016), Dalla Palma *et al.,(*2001) Coll *et al.,* (2002) and Jendeberg *et al.,* (2018) studied urolith size as a function of spontaneous passage rates (Table 5.4). All the aforementioned authors found that urolith size >5mm was directly proportional to intervention rates. Similarly, the current study found that intervention rates increased with urolith size and amount of uroliths present. In cases where intervention was applied when uroliths size was <5mm, there were multiple uroliths present.

The characteristics of the uroliths (location, number and size) are important factors to consider when selecting a treatment approach (Smith *et al.,* 2013). In the current research study urolith, size and number were shown to be a major determinant for intervention in acute urolithiasis. Therapeutic efficacy of the UECT KUB protocol increased when urolithiasis is absent as it facilitates the referral processes to relevant specialties where needed.

Table 5.4 Comparison of historic research on urolith size as a function of intervention rate

Author	Urolith size as a function of increased intervention rate	Intervention likelihood
Coll *et al.,* (2002)	>5 mm	increased
Dalla Palma *et al.,* (2001)	>5 mm	increased
Gervaise *et al.,* (2016).	>5 mm	increased
Jendeberg *et al.,* (2018)	>5 mm	increased
Current study	**>5 mm**	**increased**

The data of the current study showed that urolith size and amount of uroliths present appear to influence intervention rates greatly. The records indicated that interventions were required for 13% of uroliths (n=27) that had a maximum diameter < 5mm. The other 86% of uroliths (n=174) all had diameters ≥ 5mm.

5.4 Strengths and Limitations of this research study

The current study was limited by the cross-sectional nature. The convenience sampling method employed during this research study limits the ability of it to generalise the results. Three hundred and four records (304) had to be excluded because images seemed to be corrupted or due to administrative errors and could not be reviewed. Image corruption is a known limitation encountered with a PACS as a data collection tool as noted by Doran, *et al.,* (2012).

The strengths of the study are the inclusion of data of both men and women, the analogous sample size compared to similar studies that also studied the detection and diagnosis of uroliths using UECT KUB. All UECT KUB procedures were performed with the same CT machine with the same parameters to ensure improved control of the sample. The structured format of radiological reports also made data collection more efficient.

5.5 Recommendations

The current study focused on three levels of efficacy to evaluate the diagnostic efficacy of an imaging protocol, therefore future research may focus on all seven levels of efficacy. A prospective study may address evaluation of efficacy in a much more robust manner. The findings suggest that the protocol may be changed to enhance workflow, especially after hours. In an after-hours setting, the radiographer at the study site provides a service to the entire hospital. Therefore any time spent occupying radiology equipment must be optimised. The time it takes for the radiographer to await a response from the radiologist to confirm if any additional imaging is required may be used to attend to other important tasks involving the after hour service. The researcher believes that UVJ uroliths may be measured and if found to be ≥5mm, a prone re-scan of the bladder could be performed without waiting for the radiologist. This opinion is based on findings of the current study and similar studies by Levine, *et al.,* (1999) and Meissnitzer *et al.,* (2017) that urolith size influences intervention rates.

5.4 Conclusion

This study showed that the detection rate (DAE) of urolithiasis with the UECT KUB was higher than the non-urolithiasis detection rate, an indication that clinicians are making appropriate patient referrals for UECT KUB. Furthermore, the detection of other pathologies (DTE) allowed patients to be referred to specialists. The therapeutic efficacy (TPE) of those with confirmed uroliths on UECT KUB showed that the likelihood of intervention increased if uroliths were ≥5mm in size. . The UECT KUB has thus shown its value for detecting uroliths, non-urolith pathology and allowing for appropriate patient management, all of which contribute to effective workflow and patient care.

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APPENDICES

Appendix A: Study site permission letter

[redacted]

11 October 2018

Permission to conduct a research study

Re: Georgell Van Wyk (South African ID: 8307185173086)

This letter serves to confirm permission for Georgell van Wyk to complete his research study at our facility to evaluate the diagnostic efficacy of the current CTKUB protocol applied at the research site for detecting suspected acute urolithiasis.

Please contact me should you have any queries in this regard.

Yours sincerely,

[redacted]

[redacted]

Appendix B: CPUT Ethics certificate

Cape Peninsula University of Technology

HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)
Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
Tel: +27 21 959 6917
Email: sethn@cput.ac.za

18 January 2019
REC Approval Reference No:
CPUT/HW-REC 2019/H2

Dear Mr Georgell Shareef Van Wyk

Re: APPLICATION TO THE HW-REC FOR ETHICS CLEARANCE

Approval was granted by the Health and Wellness Sciences-REC to Mr Van Wyk or ethical clearance. This approval is for research activities related to student research in the Department of Medical Imaging and Therapeutic Sciences at this Institution.

TITLE: **Diagnostic efficacy of Computed Tomography for suspected acute urolithiasis**

Supervisor: Mrs F Davidson and Mrs V Daries

Comment:

Approval will not extend beyond 19 January 2020. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

The investigator(s) should understand the ethical conditions under which they are authorized to carry out this study and they should be compliant to these conditions. It is required that the investigator(s) complete an **annual progress report** that should be submitted to the HWS-REC in December of that particular year, for the HWS-REC to be kept informed of the progress and of any problems you may have encountered.

Kind Regards

Dr. Navindhra Naidoo
Chairperson – Research Ethics Committee
Faculty of Health and Wellness Sciences

Appendix C: Sample data collection sheet

Patient number	Gender M/F	Previous CTKUB YES/NO	Clinical symptoms	No Pathology	Urolith detected YES/NO	Prone needed YES/NO	Location of urolith	Urolith size	Extra urinary Pathology detected (DTE)	Urology interventi on. (TPE)
			‘							