THE EFFECTIVENESS OF PRE-PUNCTURE LUMBAR SPINE ULTRASOUND SCANNING IN SPINAL ANAESTHESIA FOR CAESAREAN SECTION

DR. CONSOLATA NJOKI KINUTHIA

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STUDENT'S DECLARATION

This dissertation is my original work and has not been submitted for a degree at any other university.

Dr. Consolata Kinuthia

Signature: …………………..………………….. **Date**: …………………..……….

SUPERVISORS' APPROVAL

This dissertation has been submitted for examination with our approval as university supervisors.

Dr. Muriithi Mwiti
Lecturer and Anaesthesiologist
Anaesthesia Department
University of Nairobi

Signature: …………………..………………….. **Date**: …………………..……….

Dr. Julius Muriithi
Lecturer and Anaesthesiologist
Anaesthesia Department
University of Nairobi

Signature: …………………..………………….. **Date**: …………………..……….

Dr. Stephen Mwangi
Consultant Regional Anaesthesiologist
Naivasha Level 5 Hospital
Nakuru County

Signature: …………………..………………….. **Date**: …………………..……….

Dr. Chacha Magabe
Lecturer and Interventional Radiologist
Radiology department
University of Nairobi

Signature: …………………..………………….. **Date**: …………………..……….

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LIST OF ABBREVIATIONS

CSF:	Cerebrospinal fluid
SSD:	Subarachnoid Space Depth
SED:	Skin to epidural space distance
ED-US:	Estimated depth using ultrasound
ED-N:	Estimated depth using needle measurement
CNS:	Central Nervous System
BMI:	Body Mass Index
BP:	Blood Pressure
C/S:	Caesarean Section
IV:	Intravenous
GA:	General Anaesthesia
LA:	Local Anaesthesia
NSAID:	Non-steroid anti-inflammatory drugs
COPD:	Chronic obstructive pulmonary disease
PRN:	Pro re nata (when necessary)
MRI:	Magnetic Resonance Imaging
KNH:	Kenyatta National Hospital
UoN:	University of Nairobi
ERC:	Ethics and Research Committee
RR:	Risk ratio
RCT:	Randomized controlled trial
U/S:	Ultrasound
IPPV:	Intermittent positive pressure ventilation
COPD:	Chronic obstructive pulmonary disease

OPERATION DEFINITIONS

Tuffier's line: This is the line joining the two iliac crests posteriorly. In this study the tuffier's line will be determined through palpation and will be presumed to cross the L3 vertebra or the L3/L4 interspace.

Median approach: In this approach the needle is inserted at the midline of the spine through the interspinous ligament.

Perpendicular insertion of the spinal needle: The needle is inserted at a 90 degree angle to the plane of the back of patient.

Cutting tip needle: This needle has a bevel at the end with a sharp tip. It cuts through the dura fibers to get to the subarachnoid space.

Pencil point spinal needle: This needle has a rounded atraumatic tip that acts to separate the dura fibers. The opening is at the side of the needle.

Sitting position: Patient is seated up straight with the legs extended on the operating table or resting on a stool. The neck should be flexed forward to arch the back outwards. The hands may rest the knees or on a pillow.

Lateral recumbent position: Patient lying on his side with his back parallel to the side of the operating table. The thighs should be flexed and the neck flexed forward.

Spinal anaesthesia: Also referred to as spinal block or subarachnoid block. This is a form of regional anaesthesia involving the injection of a local anaesthetic into the intrathecal space.

Successful spinal block: Sensory and motor blockade achieved within 15 minutes of injection of local anaesthetic into the subarachnoid space.

Failed spinal block: No signs of sensory and motor blockade 15 minutes after injection of the local anaesthetic into the subarachnoid space.

Good ultrasound visibility: The anterior complex and the posterior (ligamentum flavum-dura matter) complex are well defined.

Moderate ultrasound visibility:	Only the anterior complex or the ligamentum flavum-dura matter complex can be visualized.
Poor ultrasound visibility:	None of the structures are well defined.
Good palpation:	Can easily palpate the iliac crests and spinal processes.
Moderate palpation:	Can either palpate the iliac crests or the spinal processes.
Poor palpation:	Neither of the bony surfaces can be palpated.
Puncture attempt:	Every needle advancement after complete withdrawal of the needle from the skin will be considered a puncture attempt.
Needle Redirection:	Every incomplete withdrawal of the needle to change its direction of advancement.
Multilevel Puncture:	Lumbar puncture is attempted at more than one intervertebral level.
Failed attempt under ultrasound guidance:	Total of 5 puncture attempts will be considered a failed attempt and the anaesthesia provider can choose to try the landmark palpation approach or convert to general anaesthesia.

ABSTRACT

Background

Spinal anaesthesia is commonly used as a method of regional anaesthesia for surgeries below the level of the umbilicus. It is a safe substitute to general anaesthesia. It has been in existence since late in the 19th century. It is easy to learn the technique and needs lower amounts of local anaesthetics. This has made it a popular method of regional anaesthesia. Identification of the puncture site is accomplished by either palpation or by pre-puncture ultrasound guidance. The palpation method uses the tuffier's line to determine the spinal level. This has been shown to be inaccurate in previous studies. Patients with difficult to palpate landmarks pose a challenge to the anaesthesia care provider which in turn may lead to increased number of puncture attempts and patient discomfort. Pre-puncture lumbar spine ultrasound allows the anaesthesia care giver to identify the midline, intervertebral space and subarachnoid space depth before performing lumbar puncture for spinal anaesthesia.

Study Objective

To determinethe effectiveness of pre-puncture lumbar spine ultrasound as a guide to performing spinal anaesthesia in obstetric patients.

Materials and methods

Study design: This was a prospective descriptive observational study exploring lumbar spine ultrasound as a guide to spinal anaesthesia for obstetric patients. Ultrasound had been used before to guide spinal anaesthesia in patients with difficult landmarks and those in whom the palpation method completely failed.

Study site: The study was conducted in KNH and Naivasha level 5 maternity theatres.

Methodology: Patients selected for the study underwent a pre-puncture lumbar spine u/s that identified the L3/4 and L4/5 vertebral levels, the midline and the skin to subarachnoid space depth was measured. These guided performance of the lumbar puncture for spinal anaesthesia.

Data collection and analysis

Data collected included number of successful punctures, number of attempts and redirections, traumatic punctures and skin to subarachnoid space distance. Data was entered and analysed with the use of IBM SPSS version 21.0. Clinical measurements were presented as means and standard deviation, and where applicable median values. Proportion of successful LPs following ultrasound was presented as a percentage.

Results

There was a 92.2% success rate in lumbar punctures following lumbar spine ultrasound. The first attempt success rate was 71.6%. The tuffier's line was found to cross at the L3 vertebral level in the majority of the patients (65.6%) with a total of 93.3% having it crossing above the L4 vertebral level. Only 2 patients (2.2%) experienced paraesthesia during puncture and no bloody attempts were reported. There was a statistical difference between ED-US and ED-N in this study (p= 0.397).

Outcome measures

This study showed the usefulness of ultrasound in identification of ideal puncture site for spinal anaesthesia while describing the pattern of traumatic punctures and level of satisfaction experienced by the patient.

1.0 CHAPTER ONE: INTRODUCTION

Spinal Anesthesia is commonly used as a form of regional anaesthesia in developing countries. This mode of anaesthesia dates back to the 19th century when it was first delivered[1,2]. It is used for caesarean sections, lower abdominal and lower limb surgeries.

It is a safe and inexpensive method of regional anaesthesia. It requires less technical skill in comparison to epidural anaesthesia and peripheral nerve blocks. This makes it suitable in resource constrained regions.

1.1 Anatomy of the spine

The spinal cord terminates at L2 vertebral level in adults and L3 in children. It is important for lumbar puncture to be performed below these levels. The local anaesthetic is injected into the subarachnoid space for the spinal block to take place. The layers traversed by the spinal needle include the skin, subcutaneous fat, supraspinous ligament, interspinous ligament, ligamentum flavum, epidural space, dura matter, subdural space, arachnoid matter and subarachnoid space, in that order.

1.2 Sonoanatomy of the spine

Lumbar spine ultrasound is done using two views. The parasagittal view identifies the sacrum and the vertebrae at their correct levels. The transverse view identifies the midline while giving the distance from the skin to subarachnoid space. It is through the transverse view that one aims to see the posterior and anterior complexes.

1.3 Pre-puncture lumbar spine ultrasound for spinal anaesthesia

Ultrasound has been gaining popularity in the field of regional anaesthesia. It is relatively cheap and safe to perform. It may be a useful pre-anaesthesia assessment tool to predict feasibility of neuraxial blockade[3]. This is because one visualises the anatomy of the lumbar spine for each patient thus aiding in choice of appropriate spinal level and spinal needle length. It is currently not frequently used for this assessment because of lack of knowledge in spinal sonoanatomy.

The use of ultrasound for lumbar puncture was first described in1971 by Bogin and Stulin in their publication: *application of the method of 2-dimensional echospondylography for determining landmarks in lumbar punctures*[4]. The evidence supporting the use of ultrasound for spinal and epidural blocks has become stronger since. It helps in identifying intervertebral space levels, the midline and to estimate the skin to subarachnoid space distance. Use of ultrasound has been shown in previous studies to reduce the number of needle insertions and redirections. Nassar, et al in their RCT report a success rate of 62.7% on first attempt of combined spinal epidural blocks in pregnant patients when ultrasound is used compared to 40% in the palpation group[5]. This is comparable to Chin, et al who reported success rate of dural puncture at 65% when ultrasound is used and 32% when only palpation is used. It has also been shown to reduce the risk of traumatic needle insertions and increase patient satisfaction during spinal anaesthesia[6].

Pre-puncture spinal ultrasound has been found to be particularly useful in patients whose iliac crests and lumbar spinous processes are not easily palpable. These include, obese patients, patients with oedema of the back, abnormal spine anatomy such as scoliosis, previous spine surgery and pregnant women.

Pregnant patients are associated with generalized tissue oedema, weight gain and an exaggerated lumbar lordosis all which make palpation of landmarks for spinal block difficult[7,8]. This group would benefit from lumbar spine ultrasound prior to spinal anaesthesia.

This study aimed to describe the use and effectiveness of pre-puncture spinal ultrasound as a guide to performance of lumbar puncture for spinal anaesthesia.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 History of Spinal Anaesthesia

The first ever spinal block was done accidentally by James Leonard Corning in 1878[1]. In his research, as described in his publication on *spinal anaesthesia and local medication of the cord,* Corning injected cocaine into the subcutaneous tissues between two spinal processes. He reasoned the cocaine would be absorbed into the bloodstream and transported to the cord where it would cause anaesthesia of the sensory and motor tracts to mimic transverse myelitis or cord transection. In one of his subjects who suffered from spinal weakness and seminal incontinence, Corning injected 2 milliliters of 3% cocaine in the T11/T12 interspace. No effect was observed in 6-8 minutes. Within 10 minutes of repeating the injection, the subject reported that his legs felt sleepy and this advanced over the next 15-20 minutes. Corning was able to demonstrate greatly impaired sensitivity to pin prick and electrical current in the lower limbs, groin and lumbar region. There was no motor weakness or gait disturbance. The next morning the patient complained of a headache and vertigo. Corning could have inadvertently punctured the dura matter leading to post dural puncture headache.

Following Corning's publication, fourteen years later a German surgeon, Dr. August Bier, carried out the first series of successful spinal anaesthesia following advances in the field of lumbar puncture. In his publication, *Experiments on cocainization of the cord* ,Bier describes six cases in which spinal anaesthesia was administered[2]. The first one was carried out in the year 1898 on a patient who was undergoing resection of a tuberculous ankle joint. His description of the process is similar to the procedure carried out in modern times. He describes positioning of patients in a left lateral position, infiltrating the skin and subcutaneous tissue with cocaine, advancing a long hollow needle, observing cerebrospinal fluid flow and finally injecting the anaesthetic into the dural sac. He further goes ahead to document adverse effects he observed including headache, vomiting, leg and back pain. Bier and his assistant Dr. Hildebrandt performed spinal anaesthesia on one another to further study the field. He observed that spinal anaesthesia is only successful if there is at least some backflow of cerebrospinal fluid, post-dural puncture headache is the most common problem after spinal anaesthesia and that volume of CSF lost is related to the occurrence of post-dural puncture headache.

2.2 Role of Spinal Anaesthesia

Spinal block may be used solely for anaesthesia or in combination with epidural anaesthesia, general anaesthesia and peripheral nerve blocks. Spinal anaesthesia produces a dense sensorimotor blockade and sympathetic blockade while using very small doses of local anaesthetic. This makes local anaesthetic toxicity after spinal anaesthesia very rare.

2.2.1 Indications for Spinal Anaesthesia[9,10]

These include surgeries below the level of the umbilicus. This is because achieving adequate spinal anaesthesia for procedures above the umbilicus would likely lead to compromise of hemodynamic stability and the respiratory effort. Examples surgeries performed under spinal anaesthesia include; caesarean sections; obstetric procedures other than C/S such as repair of perineal tears and macdonald stitching for cervical incompetence; gynaecological procedures e.g. vulvoplasty, fistula repair and cervical polypectomy; lower abdominal surgeries e.g. inguinal hernia repairs and appendectomies; perineal surgeries e.g. anal dilatation and haemorrhoidectomy; lower limb surgeries e.g. fracture fixation and resection of tumors.

Spinal anaesthesia is the preferred choice of anaesthesia for the elderly patients and those with chronic systemic diseases such as hypertension, diabetes, liver and kidney disease because of its local effects. The vasodilatory effects of spinal anaesthesia may be beneficial to patients with mild cardiac disease.

In obstetrics spinal anaesthesia is the preferred choice for several reasons. Firstly, the anaesthesiologist avoids handling a difficult airway. Secondly, multiple drugs usually given during GA are avoided some of which may cross the placenta and cause respiratory depression in the foetus e.g. opioids and benzodiazepines. Another advantage is that the mother gets to witness and experience the birth of her child.

2.2.2 Contraindications for Spinal Anesthesia [9,10,11]

Absolute contraindications

It is important to explain fully to the patient the advantages and disadvantages of spinal anaesthesia after which the decision is made by the patient. If after conveying all the information the patient still declines spinal anaesthesia, then this should be respected.

Patients with increased intracranial pressure should not receive spinal anaesthesia. This is an absolute contraindication for spinal anaesthesia as it may lead to coning of the brainstem and death.

Spinal anaesthesia should never be attempted if the patient has a history of allergic reaction to local anaesthetic drugs. Another absolute contraindication is skin sepsis at the spinal site as this would introduce microbes into the CNS.

In case of inadequate resuscitation drugs and equipment, spinal anaesthesia should not be attempted. Necessary medications such as the vasoconstrictors must be available as well as various equipment needed for ventilatory support in case of any complications.

Relative contraindications

Some groups of patients may be difficult to control. For example, some children may not be cooperative long enough for spinal anaesthesia to be administered. The other group is psychiatric patients and patients with confusion due to head trauma. It is important to do a proper preoperative assessment of these patients before deciding on the method of anaesthesia.

Some patients with conditions such as severe osteoarthritis of the hips or unstable pelvic fractures may prove a challenge to position well for a spinal block and may not be suitable for spinal anesthesia.

Patients with a low platelet count or an abnormal coagulation profile such as those on anticoagulants or those with liver disease are at risk of forming a haematoma which may compress the spinal cord leading to severe back pain and neurological deficit commensurate with the level of the haematoma. The anaesthesia care provider should assess this risk before giving spinal anaesthesia.

Another relative contraindication is hypovolaemia. This may be due to bleeding, diarrhoea or vomiting. Resuscitation of these patients with intravenous fluids or blood should be done before administration of spinal anaesthesia.

Progressive neurological disease is considered a relative contraindication to spinal anaesthesia because it would be difficult to determine if spinal anaesthesia is the cause of new neurological deficits.

Rapid sympathetic blockade during spinal anaesthesia can reduce cardiac output leading to cardiac arrest and death in patients with fixed cardiac output states. Therefore epidural and continuous spinal anaesthesia are preferred for patients with fixed cardiac output states.

2.3 Advantages of Spinal Anaesthesia[10]

When skillfully done spinal anaesthesia has been shown to give satisfaction to patients. In a study done by Dr. Alex Kasuku on maternal satisfaction after spinal anaesthesia in Kenyatta National Hospital, he found that satisfaction with the choice of spinal anaesthesia was 80%[12]. Similar studies by T. Kumaravadivel, et a[13]l and Siddiqi, et al[14] showed a satisfaction rate of 97% and 81.4% respectively.

In comparison to general anaesthesia, spinal blocks are much more cost effective as the drugs used are fewer than and not as expensive as intravenous and inhalational agents. Chakladar, et al in their study on cost estimates for spinal versus general anaesthesia in patients undergoing surgeries for fractured neck of femur, found that the cost of spinal anaesthesia was much less than that of general anaesthesia with a p value <0.0001[15]. This was comparable to the study done by Walcott, et al on cost analysis of spinal and general anaesthesia for the surgical treatment of lumbar spondylosis[16].

Subarachnoid block produces excellent muscle relaxation in the body below the level of the umbilicus making surgical manipulation easier. In his article *on spinal anaesthesia, a surgeon's standpoint*, Robert Scarborough stated that spinal anaesthesia gives better muscle relaxation than general anaesthesia even with the use of muscle relaxants[17].

Another advantage of spinal anaesthesia is that there is no need for airway manipulation provided the block isn't high, that is, above T4 level. The patient continues to breathe spontaneously. This eliminates risks, for example, aspiration as may be seen in general anaesthesia.

Spinal anaesthesia is suitable for patients with chronic illnesses. Spinal block has minimal effects on the respiratory system making it suitable for patients with respiratory diseases. GA, specifically endotracheal intubation and IPPV has been shown to lead to poor outcomes in patients with COPD as they are susceptible to laryngospasms, bronchospasms, barotrauma, hypoxaemia and have higher rates of post-operative respiratory compromise. Regional anaesthesia such as spinal anaesthesia is therefore preferred in such patients. It is also advantageous to diabetic patients as they can resume their feeding and medication soon after surgery because effects such as sedation and post anaesthesia nausea and vomiting associated with general anaesthesia are often absent.

Spinal anaesthesia leads to a reduction in intraoperative blood loss. Modig J. in his article on regional anaethesia and blood loss noted that the lower arterial blood pressure, central venous pressure and peripheral venous pressure that is the result of spinal or epidural anaesthesia leads to less blood loss from the surgical field and subsequently reduces the need for blood transfusion[18].

There is a lower incidence of deep venous thrombosis and pulmonary thromboembolism in patients who undergo spinal anaesthesia than those who undergo general anaesthesia. Davis FM, et al looked at deep venous thrombosis and the type of anaesthesia used in patients who underwent emergency hip surgery[19]. They found that 76% of the GA group had deep venous thrombosis compared with 46% of the subarachnoid block group. A different study by Mckenzie PJ, et al compared the effects of spinal anaesthesia and GA on deep vein thrombosis[20]. They found that 76% of the GA group and 40% in the subarachnoid block group had deep venous thrombosis.

2.3 Disadvantages and Complications of Spinal Anaesthesia[11]

Hypotension is one of the commonest disadvantages or complications of spinal anaesthesia. This may be viewed by some anaesthesia care providers as an indication that a spinal block is successful. This may occur with higher blocks and the anesthesiologist must be prepared to handle this and have all the vasopressors, other resuscitation drugs and equipment at hand. If not promptly managed, hypotension can lead to cardiac arrest, ischemic organ damage and death. Shiroyama K, et al studied the cause of hypotension during spinal anaesthesia and found that more than half of the patients with a spinal block level of T5 or higher had significant hypotension[21].

The most feared complication of spinal anaesthesia is sudden cardiac arrest. A study by Auroy, et al found the incidence of cardiac arrests following spinal blocks to be at 6.4 ± 1.2 per 10,000 which is higher compared to that of epidural anaesthesia which stands at 1 for every 10,000[22]. Resuscitation equipment and medications should always be kept ready before performing spinal anaesthesia.

A spinal block may at times fail. Sometimes it may prove impossible to locate the subarachnoid space and in other cases failure of anaesthesia despite flawless technique. P. Fettes, et al states the failure rate to be less than 1% with experienced practitioners ,however, higher figures(17%) have been quoted from an American teaching hospital[23].

Performance of a subarachnoid block may take more time than general anaesthesia, more so in the less experienced practitioner. This makes it less popular with some anaesthesia care provider. The duration may however lessen with more experience.

Spinal anaesthesia is generally not suitable for surgeries lasting longer than 2 hours and may necessitate conversion to general anaesthesia. Guglielmo L, et al did a study on conversion of spinal anaesthesia into general anaesthesia and found that most conversions (49.3%) were due to insufficient spinal anaesthesia for prolonged duration of surgery[24].

Proper aseptic technique is important when performing spinal anaesthesia. Improper technique risks introduction of infection causing microbes into the CNS. Cases of severe infections in the CNS such as abscesses, arachnoiditis and meningitis are rare. Kilpatrick and Girgis did a retrospective study on meningitis following spinal anaesthesia[25]. They reviewed records of patients admitted to the meningitis ward in Cairo, during a 5 year period. 17 out of 1429 patients admitted with meningitis had recent spinal anaesthesia performed on them. The patients developed symptoms of meningitis 2-30 days after spinal anaesthesia and 10 out of the 17 had positive CSF cultures.

Post dural puncture headache was one of the most common complications following spinal anaesthesia. This has now become less frequent with the use of smaller gauge spinal needles and pencil point needles.

Another complication is transient neurological symptoms. This complication is rare following spinal anaesthesia. It consists of paradoxical post-operative back pain radiating to the buttocks and lower extremeties with no neurologic deficits. It is more common when lignocaine is used for spinal anaesthesia versus bupivacaine, prilocaine, procaine and mepivacaine. Another contributing factor is the lithotomy position on the operating table. The pain is usually not associated with any neurological pathology and resolves spontaneously by the fifth day.

Formation of epidural haematomas is a rare but devastating complication. It is easily mistaken as prolonged effects of spinal or epidural anaesthesia which delays diagnosis and management. The incidence following spinal anaesthesia is 1:220000 as reported by Tryba M, et al[26]. The haematoma compresses spinal nerves causing various irreversible damage of varying degree.

Adhesive arachnoiditis is a complication of spinal anaesthesia where the leptomeninges become fibrotic and adherent to each other, the cord and dura with resultant obliteration of the subdural and subarachnoid spaces except for cyst-like pockets filled with xanthochromic fluid. Scarring of the meninges causes pronounced constriction of the cord. Blood supply to the cord may become impaired. It presents as progressively worsening back and leg pain followed by delayed neurological deficit of varying severity.

Direct injury to the paravertebral musculature or ligamentous structures during spinal anaesthesia leads to back pain of varying intensity. Choice of site of puncture could lead to trauma to the conus medullaris with resultant intramedullary injection of local anaesthetic.

This will lead to mechanical and myelolytic destruction of the cord. Similar trauma may occur with inadvertent intraneural injection of the nerve roots. Auroy, et al did a survey that showed 61.7% of the patients who suffered neurological complications such as cauda equina syndrome, paraplegia and radiculopathy, were associated with paraesthesia or pain during injection suggesting nerve trauma and intraneural injection[22]. Horlocker, et al did a retrospective review of 4767 spinal anaesthesia performed on patients. They found that 6.3% of the patients experienced paraesthesia during needle placement with six patients reporting persistent paraesthesia[27]. Direct needle trauma is one of the preventable causes of neurological damage thus one should withdraw the needle in case of paraesthesia to avoid postoperative radiculopathy. Other factors contributing to neurological damage post spinal anaesthesia include improper patient positioning and multiple attempts (Hebl JR et al[28]).

2.5 Anatomy and Physiology of Spinal Anaesthesia

2.5.1 Functional Anatomy of Spinal Blockade

The spinal cord terminates at L2 vertebral level in adults and L3 in children. Thus spinal block above the L3 vertebral level should not be carried out to avoid cord injury.

The following structures are traversed by the spinal needle during the median approach of spinal anaesthesia:

Skin: This layer contains nociceptors thus injection of local anaesthetic is adviseable before performing the spinal anaesthesia.

Subcutaneous fat: This layer is of variable thickness. The thicker it is the harder it might be to palpate the intervertebral space.

Supraspinous ligament: This connects the apices of the spinous processes of vertebrae from C7 to the sacrum.

Interspinous ligament: Connect the spinous processes together.

Ligamentum flavum: It connects the laminae of consecutive vertebrae together. It is also known as the yellow ligament. It is quite thick and mostly made up of elastic tissue. The spinal needle will feel 'gripped' while in this layer and a certain 'give' is perceived as it goes through the ligamentum flavum into the epidural space.

Epidural space: This space contains blood vessels and fat. A traumatic (bloody) tap is likely to be due to puncture of an epidural vein and the needle should be advanced deeper.

Dura matter: This is the outermost and toughest layer of the 3 membranes that protect the cord

Subdural space: This is the space that separates the dura matter and the arachnoid matter.

Arachnoid matter: The middle cobweb like layer of the membranes

Subarachnoid space: This contains the CSF, the spinal cord and the nerve roots. The local anaesthetic, once injected into the CSF, causes anaesthesia of the cord and nerves that absorb the drug.

If a paramedian approach is taken during spinal anaesthesia the following structures are traversed in this order: skin, subcutaneous fat, ligamentum flavum, epidural space, dura matter, subdural space, arachnoid matter, subarachnoid space.

2.5.2 Surface Anatomy of Spinal Anaesthesia

The most important aspect of surface anatomy is the line joining the two iliac crests (Tuffier's or intercristal line). It has been a common statement that this line crosses the L4 vertebra or the L4/5 interspace at the midline on imaging, A study by Chakraverty, et al showed that the intercristal line formed through palpation tended to cross the midline at higher levels, i.e. L3 or L3/4 interspace, in 77.3% of the cases[29]. This was more common in women and persons with large BMI. It is therefore more prudent to assume that the intercristal line formed through palpation crosses the midline at L3 or L3/4 interspace.

Se Hee Kim in his comparison between pregnant and non-pregnant patients found that the intervertebral spaces in the pregnant group were more cephalad with the tuffier's line, which was determined through palpation, crossing at the L3 lower vertebral level and L4 lower level in the non-parturient group. He used ultrasonography to identify the vertebrae[30].

Lin, et al looked at patient factors affecting the accuracy of the tuffier's line by palpation[31]. He found that patients with larger abdominal circumferences, BMI and age between 50 and 70 years had lumbar interspaces that were higher than the presumed levels. Patients with smaller abdominal circumferences and lower BMI had intervertebral spaces lower than the presumed level. Degree of lumbar flexion however did not affect the accuracy obtained.

The dermatomes important for spinal anaesthesia include T10, which corresponds to the level of the umbilicus. This level of anaesthesia is adequate for hip, lower limb, instrumental vaginal deliveries. T6 corresponds to the level of the xiphoid process. This level of anaesthesia is adequate for urological, gynaecological and other lower abdominal surgeries. T4 corresponds to level of the nipples. At this block level, hypotension should be anticipated and managed promptly.

The block levels required for adequate anaesthesia for surgery are higher than the area of surgical incision because visceral sensory innervation occurs at higher spinal levels than the skin dermatomal levels.

2.5.3 Sonoanatomy of the lumbar spine[11,32]

The patient is placed in the sitting position with the back flexed. A low frequency (2-5 MHz) curvilinear probe is used to perform the lumbar spine ultrasound. The ultrasound probe is placed in the lower back about two centimeters from the midline with the orientation marker facing cranially. A slight medial tilt reveals a flat and hyperechoic structure which is the sacrum. When the transducer is slid upwards a gap is seen. This is the L5/S1 interspace. The L4/5 and the L3/4 can be identified by counting upwards.

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Figure 1: Positioning of the ultrasound operator and transducer while performing the parasaggital ultrasound scan

*Permission was sort from the patient.

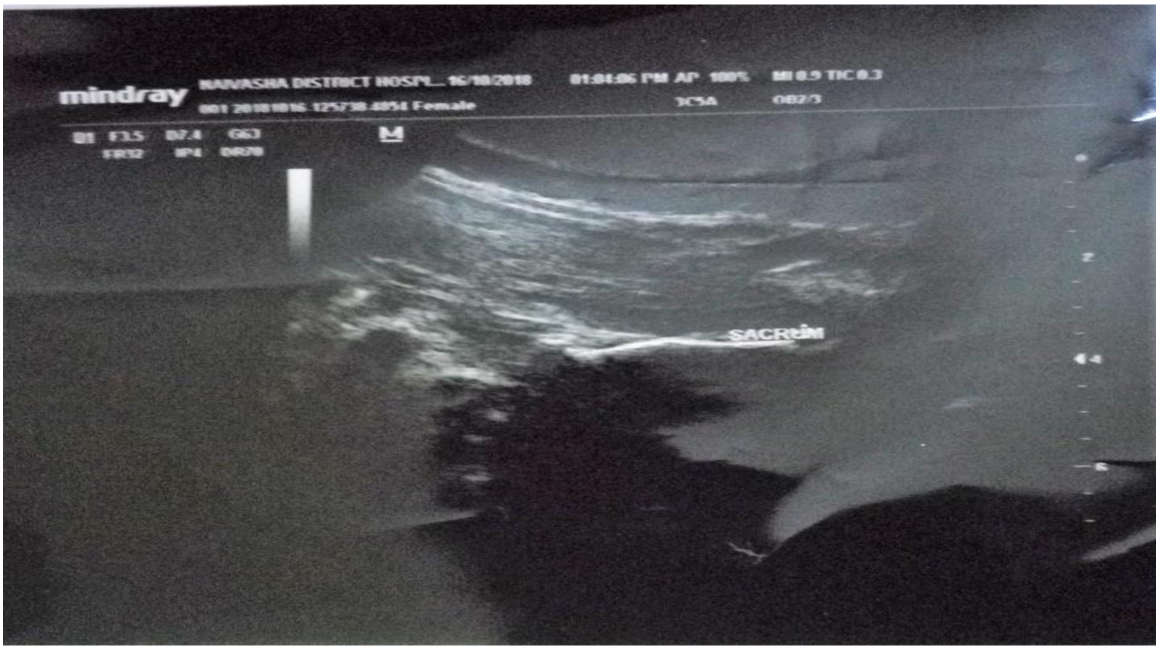

Figure 2: Paramedian sagittal ultrasound image of the sacrum.

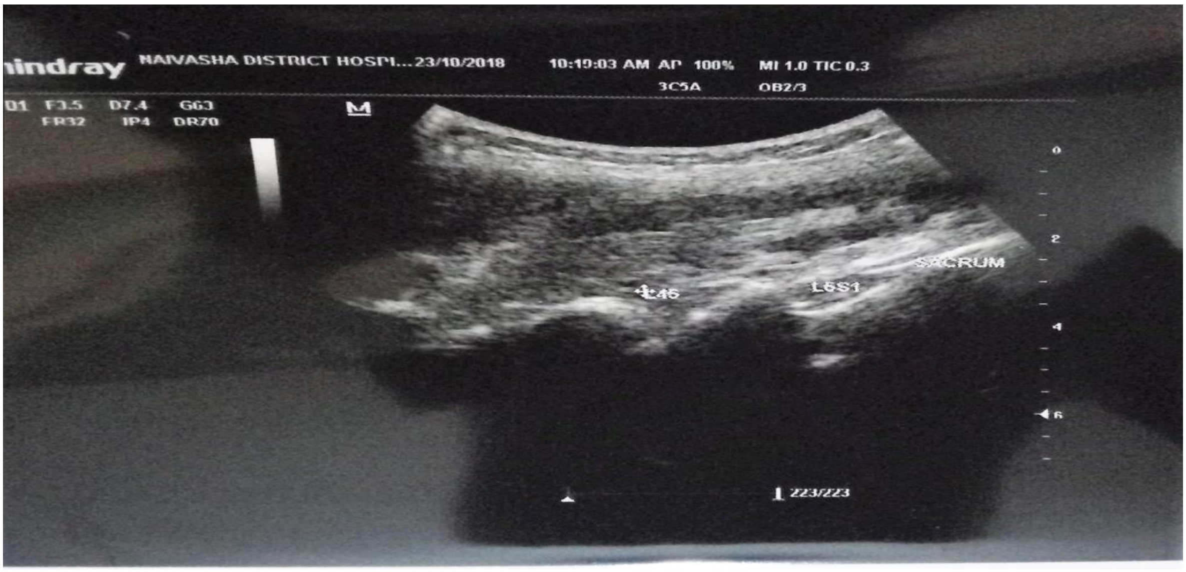

Figure 3: Parasagittal interlaminar view showing the intervertebral spaces

On the transverse scan through the intervertebral spaces the transducer is tilted cranially or caudally until the ultrasound image is optimized. In this view the ligamentum flavum, posterior dura (posterior complex) and anterior complex are visualized. It is difficult to visualize the ligamentum flavum and the posterior dura separately and they are therefore referred to as the ligamentum flavum-dura (posterior) complex. The epidural space lies between the ligamentum flavum and the posterior dura and is also rarely visualized.

Figure 4: Positioning of ultrasound operator and transducer when performing a transverse spinal ultrasound.

*Permission was sort from the patient.

Figure 5: Ultrasound image of transverse spinal ultrasound scan. LAM: lamina, PC: posterior complex, AC: anterior complex.

2.5.4 Mechanism of Action of Spinal Blockade

The local anaesthetic is injected into the CSF through the spinal needle. The drug mixes with the CSF and is absorbed by both the spinal cord and the nerve roots. The higher the surface area exposed to the local anaesthetic the higher the rate of absorption.

The spinal cord absorbs the local anaesthetic via two mechanisms. The first mechanism is diffusion from the CSF into the cord through the pia matter. This process takes a long time and the drug only anaesthetises the superficial part of the spinal cord. The second mechanism involves extension into Virchow Robin spaces. These are the areas of pia matter that envelope CNS blood vessels. The Virchow Robin spaces connect with the perineuronal clefts that surround the neuronal cell bodies of the cord and penetrate deeper into the cord.

2.6 The Obstetric Patient and Spinal Anaesthesia

Regional anaesthesia, specifically spinal block is the anaesthesia of choice for caesarian section due to its limited effects on the mother and foetus. Performance of spinal anaesthesia requires a good assessment of the spine to determine the optimum intervertebral space and the midline. The obstetric population presents unique challenges because pregnancy is associated with generalized edema, increased weight and hyperlordosis all of which make palpation of the iliac crests and spinous processes very difficult. Furthermore, hormonal changes soften the ligaments making it difficult to feel the ‘give’ when the spinal needle passes the ligamentum flavum. Positioning a gravid patient for optimum lumbar flexion can also be challenging because of the abdominal size and labor pains[7,8]. Repeated punctures and needle redirections increase patient discomfort during spinal anaesthesia.

The tuffier’s line has been shown to be an inaccurate way of estimating the intervertebral spaces in the parturient patient. Kim et al found that the tuffier’s line crosses the L3 vertebra in parturients as opposed to L4 in non-parturient patients showing that the tuffier’s line shifts cephalad in the pregnant patient[30]. Margarido, et al found it to cross at the L2/3 intervertebral space in parturients[33]. This difference between the parturient and non-parturient patients may be attributed to the hyperlordosis and spinal rotation that occurs during pregnancy.

Ultrasound has been shown to accurately identify the correct lumbar intervertebral spaces for lumbar puncture thus reducing risk of injury to the conus medullaris.

2.8 Ultrasound Guidance for Spinal Anaesthesia

Ultrasound is a useful pre-anaesthetic tool for spinal anaesthesia. Lumbar spine ultrasound is used to identify the correct intervertebral spaces, the midline, angulation needed for lumbar puncture, the skin to subarachnoid space distance.

In obstetrics, ultrasound has been used in epidural catheterizations and spinal anaesthesia leading to a reduction in number of puncture attempts and needle redirections and to improve patient satisfaction.

Nassar, et al in an RCT comparing palpation and ultrasound guidance for combined spinal epidural block found that the ultrasound group had a higher success rate on first attempt at combined spinal epidural procedure (62.7% success on first attempt)[5].The palpation group first attempt success proportion was at 40%. The ultrasound group had less puncture attempts with a mean of 1.2 while the palpation group had a mean of 2.3 puncture attempts. It took longer to identify the puncture site in the ultrasound group (9.1minutes) than in the palpation group (6.2 minutes).

Some studies have found no added advantage to use of ultrasound for spinal anaesthesia. Ansari, et al when looking at obstetric patients with easily palpable spinous processes found that when performed by anaesthetists experienced in both ultrasound and landmark techniques the use of ultrasound did not appear to add any advantages in terms of increasing the success rate of spinal anaesthesia or reduction in the procedure time[34].

Lumbar spine ultrasound has been used successfully in non-obstetric patients as a guide for spinal anaesthesia with a high record of success when done both pre-procedurally and in real time. Sree, et al used pre-procedural U/S imaging to identify the best intervertebral space for placement of spinal needle in patients aged 55 years or older undergoing elective surgeries under spinal anaesthesia[35]. They were divided into two groups. One group received spinal anaesthesia based on clinical parameters and the other based on ultrasound parameters. It was found that the number of attempts and the need to change the space or the needle was significantly lower in the ultrasound group than the clinical parameter group. It was concluded that pre-procedural ultrasound imaging is useful in predicting difficult spinal anaesthesia in older patients. It can be utilized to locate ideal space for insertion of the spinal needle.

PH Conroy ,et al, in their publication on real time ultrasound guided spinal anaesthesia found that the rate of successful lumbar punctures using real time ultrasound guidance to be 97% of the patients with median 3 needle passes[36].

Chin, et al did an RCT on ultrasound facilitated spinal anaesthesia in adults with difficult surface anatomic landmarks[6]. Only 120 patients completed the study. It was stopped early due to a significant difference in outcomes. Successful dural puncture on first attempt was 65% in the ultrasound group and (32%) in the landmark group. The median number of needle insertion attempts was 1 in the ultrasound group and 2 in the landmark group while median number of needle passes was 6 in the ultrasound group and 13 in the landmark group to achieve dural puncture.

Sherif, et al in their study on ultrasound guided intrathecal anaesthesia, divided 90 patients into two groups; the ultrasound group and the surface landmark group[37]. Successful first needle attempts were 80% in the ultrasound group and 17% in the surface landmark group. Patient's satisfaction was also higher in the ultrasound group at 95.6% compared to 77% in the surface landmark group. However, it was observed that the ultrasound group needed more time to establish landmarks.

The usefulness of ultrasound for spinal anaesthesia is further supported by Guardabassi, et al in their publication on spinal anaesthesia performed under previous ultrasound examination guidance[38]. The success rate of dural puncture at first needle passes was 75%.

Gnaho, et al assessed the accuracy of ultrasound to predict the depth to reach the lumbar intrathecal and epidural spaces[32]. In his pilot study he compared the estimated depth by ultrasound to the estimated depth by needle measurement and found that there was no significant difference making ultrasound a useful tool for spinal anaesthesia.

In contrast, Peterson, et al in their study on ultrasound for routine lumbar puncture found that there was no difference between those patients undergoing ultrasound localization versus those undergoing palpation of spinal landmarks in terms of number of attempts and success of the procedure[39]. They concluded that there was no added advantage to the routine use of ultrasound localization for lumbar puncture.

Shaikh, et al carried out a systematic review and meta-analysis assessing ultrasound imaging for lumbar punctures and epidural catheterizations[3]. A total of 14 studies (1334 patients) were included. Five studies evaluated lumbar punctures and the rest epidural catheterizations. Overall ultrasound imaging reduced the risk of failed procedures with a risk ratio of 0.21 (95% confidence interval). Risk reduction in lumbar punctures was noted in the ultrasound imaging groups with a risk ratio of 0.19. Ultrasound was also shown to reduce the risk of traumatic procedures (RR - 0.27), number of needle insertion attempts (mean difference of -0.44) and the number of needle redirections (mean difference -1.00).

3.0 CHAPTER THREE: STUDY JUSTIFICATION AND METHODOLOGY

Spinal anaesthesia is the anaesthesia of choice for caesarian section. The obstetric patient poses a challenge to the traditional landmark palpation method because of the various physical changes that occur during pregnancy. These include weight gain, tissue edema, hyperlordosis of the lumbar spine, pelvic rotation and poor back flexion due to the gravid uterus or pain during labor.

The landmark palpation method uses the tuffier's line formed to estimate the intervertebral space level which has been shown to be inaccurate as it tends to fall on higher spaces. In parturients the intervertebral spaces tend to be more cephalad than in the non- parturient patient making the tuffier's line even more inaccurate in this group of patients. Though rare, misidentification of intervertebral spaces increases the risk of needle trauma to the cord.

Ultrasound provides a safe and accurate method of identifying the correct intervertebral spaces and the midline. Furthermore, the measure of the skin to subarachnoid space depth using ultrasound may aid in appropriate spinal needle selection and guide the anaesthesia care provider on the depth of insertion.

3.1 Research Question

Is pre-puncture lumbar spine ultrasound scanning useful as a guide to spinal anaesthesia in obstetric patients undergoing caesarean section in KNH and Naivasha level 5 hospital?

3.2 Study Objectives

3.2.1 Broad Objective

To determine the usefulness of pre-puncture lumbar spine ultrasound scanning as a guide for spinal anaesthesia in obstetric patients.

3.2.2 Specific objectives

- **i.** To determine the number of puncture attempts and needle redirections done for a successful lumbar puncture following lumbar spine ultrasound scan.
- **ii.** To determine the proportion of bloody attempts and paraesthesia during performance of lumbar puncture for spinal anaesthesia following ultrasound scanning.
- **iii.** To determine the usefulness of ultrasound in predicting the skin to subarachnoid space distance.

3.3 Study Design

This was a prospective descriptive observational study.

3.4 Study Site

Maternity theatres in Kenyatta National hospital and Naivasha level 5 Hospital.

3.5 Study Population

Obstetric patients undergoing spinal anaesthesia for caesarian section in KNH and Naivasha level 5 Hospital.

3.6 Sampling Design

Consecutive sampling was applied.

3.7 Sampling Procedure

Consecutive sampling of all patients in the emergency and elective lists who met the inclusion criteria and who gave consent during the study period was done. Patients were sampled from both Naivasha and KNH maternity theatres consecutively until the sample size was achieved.

3.8 Sample Size

Sample size calculation for finite population.

$$n = \frac{Nz^2pq}{E^2(N-1) + z^2pq}$$

n = Desired sample size

N = population size (number of obstetric patients who can potentially undergo pre-puncture lumbar spine ultrasound in a day is approximately 4, and for 1 month of the study duration the total will be approximately 120).

Z = value from standard normal distribution corresponding to desired confidence level (Z=1.96 for 95% CI)

p = expected true proportion (estimated at 65.0%, from a study conducted by Chin KJ et al (2011) observed a first-attempt success rate of 65.0%)

$q = 1 - p$

E = desired precision (0.05)

$$n = \frac{120x\ 1.96^2\ x\ 0.65\ x\ 0.35}{0.05^2(120-1) + (1.96^2\ x\ 0.65\ x\ 0.35)} \simeq 90$$

3.9 Eligibility

3.9.1 Inclusion Criteria

- Patients who underwent spinal anaesthesia for emergency or elective caesarean section who gave consent to be included in the study.
- Patients who underwent spinal anaesthesia for caesarean section in combination with GA or other regional anaesthesia.

3.9.2 Exclusion Criteria

- Patients who declined to give consent.
- Patients with contraindications to spinal anaesthesia.
- Patients who required a paramedian approach for the spinal block.
- Patients with spine or back deformity.
- Patients unable to sit for spinal anaesthesia.
- Obstetric patients who underwent non-obstetric procedures under spinal anaesthesia.
- Obstetric patients who underwent obstetric procedures other than C/S.

3.10 Study Procedure

Pre-anaesthesia review of all eligible patients was done in the ward for elective cases and at the receiving area for emergencies, including obtaining an informed consent for the study. Consecutive sampling was done in theatre upon receiving emergency and elective theatre lists.

In the theatre receiving area, the age, sex, weight and height of the patient were recorded. The body mass index was calculated using the quetelet index (weight in kg/height in m^2). The patient was placed under standard monitoring devices i.e. electrocardiogram, non-invasive blood pressure and pulse oximetry. Baseline vitals were recorded.

The patient was placed in the sitting position with the back flexed. The palpability of the anatomic landmarks was assessed and recorded as good, moderate or poor. The ultrasound scan was then performed by anaesthesia providers trained in lumbar spine ultrasound by a consultant radiologist. This included myself and Dr. Stephen Mwangi, the regional anaesthesiologist in Naivasha level 5 hospital. The curvilinear ultrasound probe was placed over the sacrum 2 centimeters from the midline to perform a parasagittal scan. The sacrum was identified as a hyperechoic line. The probe was then moved cephalad to obtain hyperechoic saw like images representing the articular processes and interspaces were counted upward. The L4/5 and L3/4 interspaces were identified and marked on the patient using a skin marker. A transverse scan was then performed at these interspaces and the midline noted and marked. The optimum image obtained was frozen on the screen. The aim was to visualize anterior complex and the ligamentum flavum-dura matter (posterior) complex. The image was classified as good, moderate or poor. Using a measurement scale on the ultrasound screen, the distance from the skin to the anterior border of the ligamentum flavum- dura matter complex was measured and recorded as the ED-US. The marks drawn on the patient's back to note the midline and the intervertebral spaces will be extended. The points at which the lines cross shall be the points of spinal needle insertion.

Figure 6: Lines drawn to identify the L3/4 and L4/5 intervertebral spaces. Where they cross the midline will be the point of needle insertion

Intravenous access was established and co-loading with a crystalloid initiated.

The patient was placed on the operating table in the sitting position with the back fully flexed. The anaesthesia provider who performed the ultrasound was the one who performed the lumbar puncture. Using aseptic technique the clinician proceeded to perform lumbar puncture for spinal anaesthesia using the markings on the back as a guide. The choice of lumbar interspace used was at the discretion of the anaesthesia care provider. Skin infiltration with lignocaine was done at the selected interspace. The spinal needle was then introduced through the selected point with angulation of the needle being guided by the angulation of the ultrasound probe during scanning. The number of needle insertions, redirections and multilevel punctures was noted. Once the dural puncture was felt the stylet was withdrawn to confirm free flow of clear CSF. The local anaesthetic of choice was then administered carefully, following which, the needle was marked at the skin entry point with a marker before withdrawal of the needle. In case a pencil point spinal needle with an introducer was used the needle was marked at point of entry at the introducer and the introducer at the point of entry to the skin. A sterile dressing was applied at the puncture site after the withdrawal of the needle. The skin to subarachnoid space distance (ED-N), was then measured using a ruler directly for the cutting tip needle and recorded. For the pencil point needle the length of the needle was measured from the mark to the beginning of the lateral eye. The length of the introducer was measured from the point of skin entry to the end of the hub. The introducer length measured was then subtracted from the pencil point length and the difference was recorded as the skin to subarachnoid space distance in centimeters. Management of the patient continued as per the hospital protocol.

3.11 Outcome

This study was expected to show the usefulness of ultrasound in identification of ideal puncture site for spinal anaesthesia while describing the pattern of traumatic punctures and level of satisfaction experienced by the patient.

3.12 Data Collection

Data was collected using a data collection tool by the primary investigator and research assistants. The hard copies of the data collected were stored in locked cabinets and only accessed by the primary investigator and the research team.

3.13 Data Management and Analysis

Data was entered and analyzed with the use of IBM SPSS version 21.0. The data was password protected limiting access only to the research team. All clinical measurements were analysed and presented as means and standard deviations, and where applicable median values. Proportion of successful lumbar punctures following lumbar spine ultrasound was presented as a percentage. The number of puncture attempts, needle redirections and multilevel punctures were also analysed and presented as percentages. Demographic data and other clinical data that was categorical was analyzed and presented as frequencies and proportions, while those that were continuous were presented as means with their standard deviations. The results were considered significant at $p < 0.05$.

3.14 Quality Assurance

This was ensured by following standard procedures during performance of the spinal block. Lumbar spine ultrasound scans were performed by persons who underwent training by a consultant radiologist. The person who performed the lumbar spine ultrasound carried out the lumbar puncture for spinal anaesthesia for the same patient. The study tools were pretested and strict adherence to the inclusion and exclusion criteria during patient selection was ensured. The data collection procedure was also adhered to as outlined in the methodology. Data collected was cleaned before analysis began.

3.15 Ethical Considerations

- **i.** Permission was sought from Kenyatta National Hospital- University of Nairobi Ethics and Research Committee, KNH and Naivasha level 5 hospital administrations before carrying out the study.
- **ii.** Participation in the study was entirely voluntary and the participant was allowed to withdraw from the study at any point.
- **iii.** Unique numbers were used for identification purposes and each participant remained anonymous.
- **iv.** The study participants did not incur any additional costs.
- **v.** Appropriate intervention was availed to the patient in case of any side effects from the spinal anaesthesia.
- **vi.** The study findings were availed to the Kenyatta National Hospital- University of Nairobi Ethics and Research Committee and the Department of Anaesthesia.
- **vii.** At the end of the study, data was preserved in an encrypted file in soft copy and hard copies for future reference.

4.0 CHAPTER FOUR: RESULTS

4.1 Study Period

This study was approved by the KNH-UON ethics and research committee on 28th February 2019. Patients who met the inclusion criteria were recruited consecutively during the month of March until the sample size was achieved.

4.2 Patient Characteristics

This section describes the characteristics of the obstetric patients undergoing spinal anaesthesia for caesarean section.

The characteristics of the patients are as shown by the table below.

Table 1: Age and BMI

	Frequency	Percent
Age		
<18	1	1.1
18-25	29	32.2
26-35	54	60.0
36-45	6	6.7
BMI		
18.5-24.9	16	17.8
25-29.9	46	51.1
>=30	28	31.1

The mean age of the patients was 28.2 (SD=4.8), and the median age was 28.0 (IQR=7) years.

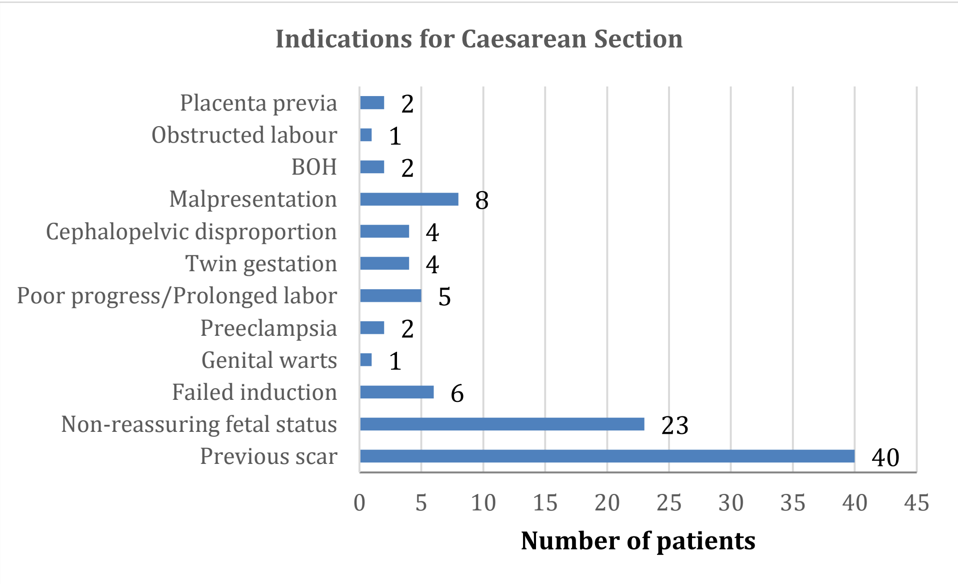

Figure 7: Indications for caesarean section

Previous Spinal Anaesthesia

37 out of 90 (41.1%) patients had a history of previous spinal anaesthesia for caesarean section.

Table 2: Palpability of anatomical landmarks

Palpability of anatomic landmarks	Number	Percentage
Good	36	40.0
Moderate	44	48.9
Poor	10	11.1

The majority of the patients (48.9%) had moderate palpability of the anatomical land marks meaning that one of either the iliac crests or spinous processes was not palpable.

4.3 Performance of the Lumbar Spine Ultrasound

The lumbar spine ultrasound scans were done using 3 types of ultrasound machines. The majority (95.6%) were done using the Well D ultrasound machine. 3.3% were done using the Mindray ultrasound machine and 1.1% the butterfly IQ portable probe.

Quality of Ultrasound Scan

The majority of the lumbar spine ultrasound scans were of good quality. This means that both the anterior and posterior complexes could be identified in the scan.

Table 3: Quality of ultrasound

Quality of ultrasound	Frequency	Percentage
Good	63	70.0
Moderate	21	23.3
Poor	6	6.7

The midline of the spine was identified in all the cases (100%). In 98.9% of the cases both L3/4 and L4/5 intervertebral spaces were identified.

4.4 Level of Palpated Tuffier's Line

The palpated tuffier's line was found to cross different intervertebral spaces as shown in the table below

Table 4 :Vertebral level at which the palpated tuffier's line crosses

Vertebral level at which the palpated tuffier's line crosses	Frequency	Percentage
L2	6	6.7
L2/L3 Interspace	7	7.8
L3	59	65.6
L3/L4 Interspace	12	13.3
L4	6	6.7

The vertebral level at which the tuffier’s line crosses was found not to correlate with BMI in this study as shown in the table below.

Table 5 : Correlation between vertebral level and BMI

	BMI			p-value
	18.5-24.9	**25-29.9**	**>=30**	
L2	1 (16.7)	0 (0.0)	5 (83.3)	0.012
L2/L3 Interspace	0 (0.0)	5 (71.4)	2 (28.6)	0.372
L3	10 (16.9)	32 (54.2)	17 (28.8)	0.710
L3/L4 Interspace	4 (33.3)	7 (58.3)	1 (8.3)	0.114
L4	1 (16.7)	2 (33.3)	3 (50)	0.566

4.5 Performance of the Lumbar Puncture

The puncture site for lumbar puncture was guided by the skin markings made during lumbar spine ultrasound scanning. Successful puncture attempts following ultrasound guidance were 92.2%.

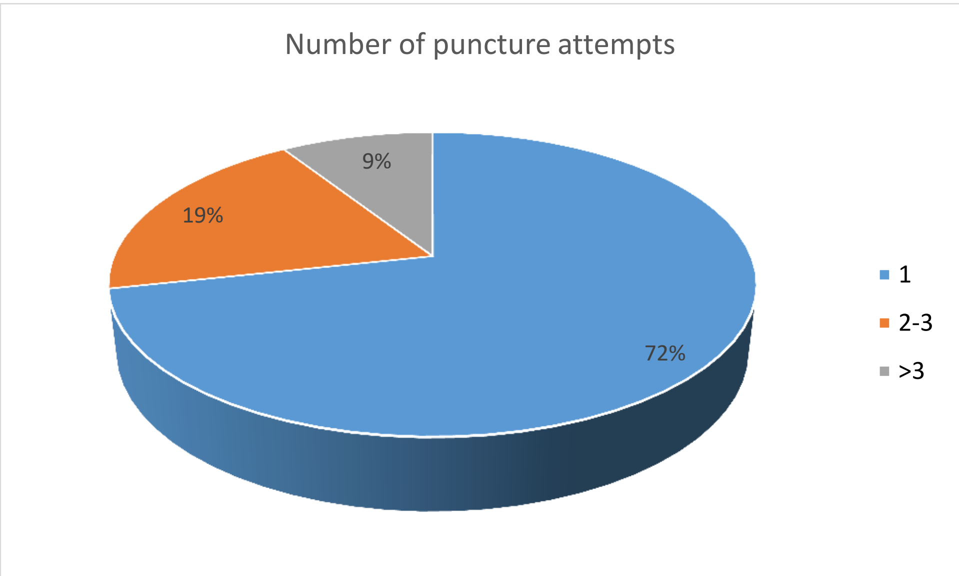

Figure 8: Number of puncture attempts required for successful lumbar puncture

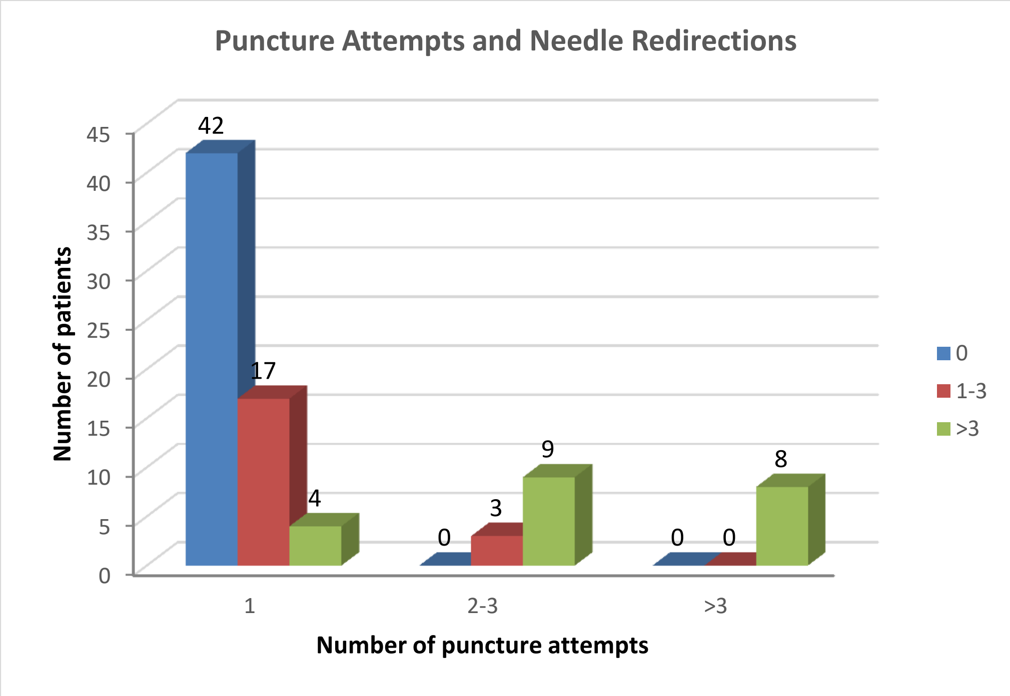

Figure 9 : Number of puncture attempts and needle redirections

4.6 Bloody Attempts and Paraesthesia

This section presents the results of the proportion of bloody attempts and paranesthesia during performance of lumbar puncture for spinal anaesthesia.

There were 2 patients that experienced paraesthesia. There were no bloody attempts.

4.7 Skin To Subarachnoid Space Distance

A comparison was made between skin to subarachnoid space distance measured using ultrasound and needle measurement and a statistical significance was demonstrated as shown in the table below.

Table 6 : Skin to subarachnoid space distance

Skin to subarachnoid space distance	N	Mean	SD	Mean Difference	p-value
Needle	90	6.246	.8336	0.3973	<0.001
U/S	87	5.848	.5488		

An independent-samples t-test was run to determine if there were differences in the skin to subarachnoid space distance measured using ultrasound and by needle measurement. The SSD measured using needle measurement was longer (6.2 ± 0.8) than the SSD measured using ultrasound (5.8 ± 0.5), a statistically significant difference of 0.4 (95% CI, 0.18 to 0.61), $t(175) = 3.72$, $p < .001$.

4.8 Patients' Satisfaction with Ultrasound Guided Spinal Anaesthesia

We asked patients who had had previous spinal anaesthesia if they found ultrasound guided spinal anaesthesia better, the same as or worse than their previous spinal anaesthesia experience. The responses were as show in the table below.

Table 7:Patients' satisfaction with ultrasound guided spinal anaesthesia

Response	Frequency	Percentage
Better	24	64.9
Same	10	27.0
Worse	3	8.1

5.0 CHAPTER FIVE: DISCUSSION

This study was carried out to determine the effectiveness of pre-puncture lumbar spine ultrasound scanning in spinal anaesthesia for caesarean section. The study was carried out in KNH and Naivasha level 5 maternity theatres. A total of ninety patients met the inclusion criteria thus recruited during the study period. Majority (60 percent) of the patients were within 25-35 years age bracket with mean and median age of 28.2 and 28 years respectively. In regard to body mass index, more than half of the patients were overweight and one third were obese. This could potent difficulty in determination of anatomical landmarks for spinal anesthesia as noted in at least two-thirds of our study population. This findings are similar to those reported by Lie et al who found obesity was the most common cause of failed neuraxial procedural technique[7].

Previous scar was the most common indication for caesarean section followed by non-reassuring fetal heart rate and malpresentation at a distant third. Moreover, 41 percent of patients who underwent spinal anesthesia had previous history of the same. Despite the fact that we used three different brands of ultrasound machines, we accurately identified the midline in all the patients. Both L3/4 and L4/5 intervertebral spaces were identified in 98.9% of the patients. Correct identification of the intervertebral spaces is of paramount importance as it reduces the risk of traumatic complications of spinal anaesthesia.

The palpated tuffier's line was demonstrated to fall above the L4 vertebral level in 93% of the partureints in the study. The tuffier's line in the majority of patients (65.6%) crossed at the L3 vertebral level. This was similar to the findings by Kim et al whereby the tuffier's line in parturients was found to be lying at the L3 vertebral level which was significantly higher than that of parturients which crossed at L4 vertebral level ($p<0.05$)[30]. Chakraverty while looking at adult patients (male and female) also concluded that the tuffier's line was inaccurate for identifying the L4 vertebral level as it tended to cross at higher levels in 77.3% of the patients[29].

There was no correlation between Tuffier's line vertebral level and body mass index of the individual patient (p value>0.05). This finding was similar to Chakraverty, et al who found that although there was a tendency for higher spinal levels to be identified the tuffier's with increasing BMI, it was not statistically significant[29]. Kim et al also found that the level of tuffier's line did not correlate with weight or BMI[30]. On the other hand Lin et al found a correlation between the vertebral level at which the tuffier's line crosses and BMI[31].

Following ultrasound guidance, we had successful punctures of 92.2%. Succesful punctures at first attempt were 71.6%. In these group 66.7% required no redirection. Other studies have been carried out with successful lumbar punctures using ultrasound guidance. Nassar, et al carried out an RCT comparing palpation to ultrasound guidance for combined spinal epidural blocks in parturients. Success rate at first attempt was 62.7% for the ultrasound group and 40% for the palpation group[5]. Chin et al did an RCT comparing pre-puncture ultrasound and palpation for spinal anaesthesia in adults with difficult anatomic landmarks. The success rate at first attempt was 65% for lumbar puncture after ultrasound. This was twice as high as the palpation group (32%)[6].
Two patients experienced paresthesia, however were no bloody attempts. The incidence of paraesthesia in our study sample was 2.2%. This was much lower than that reported by Eduardo, et al : 6.3- 20%[40]. This might partly explained by the use of ultrasound to identify appropriate levels for puncture. Shaikh et al in his metanalysis found that ultrasound reduced the risk of traumatic punctures with a risk ratio of 0.27[3].

Using independent-samples t-test, we found a statistically significant difference in the skin to subarachnoid space distance measured using ultrasound and by needle measurement (95% CI, 0.18 to 0.61, $p < .001$). In this study we found that we could not accurately predict the skin to subarachnoid space distance using ultrasound. However, Gnaho, et al did not find any statistical difference between skin to subarachnoid space distance taken using needle measurement and ultrasound measurement.

When asked about their experience of the ultrasound guided spinal anaesthesia compared to previously encountered palpation method, two thirds of the patients preferred the former. It is possible that use of ultrasound alleviates the discomfort that comes with repeated puncture attempts.

5.1 Conclusion

This study demonstrated that ultrasound is a useful tool for identification of correct intervertebral spaces for lumbar puncture. It also showed that the tuffier’s line is not an accurate method of identifying intervertebral spaces. Pre-puncture ultrasound can be used to facilitate performance of spinal anaesthesia for caesarean section.

Ultrasound may reduce incidence of paraesthesia and bloody attempts during performance of spinal though a larger randomized control trial may be needed.

5.2 Limitations

\There was difficulty in accessing an ultrasound machine in this study. 3 types of ultrasound machines were used. Due to the unavailability, inexperience in its use may have affected the results of this study.

Measurement calipers on the ultrasound machine used on the majority of patients in this study were faulty requiring an estimate using the screen scale to be used. This may have affected the results on the skin to subarachnoid space distance measurements.

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BUDGET

ITEM	UNIT COST (KSH)	QUANTITY	TOTAL (KSH)
Stationery	5000		5000
Printing	25000		25000
Study assistants	20000	2	40000
Statistician	40000		40000
ERC fee	2000		2000
Miscellaneous			10000
Ultrasound gel	500	2	1000
Sterile probe covers	40	100	4000
Total			127000

Budget justification notes

Stationery and printing costs include charges of the proposals, questionnaires and the final bound copies of the books. The statistician will charge a one-off fee of 40,000 kenya shillings. Assistants who will be assisting in filling of the questionnaires will be charging 20,000 each. I will need one assistant for each of the two study sites. The miscellaneous budget will cover for costs such as travel costs to naivasha and software installations.

STUDY TIMELINES

Activities	August to November 2018	December 2018	March 2019	April 2019	May 2019
Proposal writing	√				
Presentation to IREC		√			
Data collection			√		
Data Processing				√	
Dissertation presentation					√

APPENDICES

Appendix I: Questionnaire

PRE-PUNCTURE LUMBAR SPINE ULTRASOUND FOR OBSTETRIC SPINAL ANAESTHESIA

Serial number…………………..

Date……………………………….

Age………………

Ultrasound machine model……………………………………..

Anthropometric measurements

Weight …………………....

Height ……………………..

BMI ………………………….

Pregnancy gestation in weeks………………………

Clinical information

Indication for C/S ……………………………………

Comorbidities Diabetes mellitus ☐

Hypertension ☐

Asthma ☐

Others …………………….

Baseline vital observations

Blood pressure…………………….

Heart rate …………………………..

Respiratory rate………………….

Oxygen saturations………………

Anaesthesia team composition

A. Clinical officer anaesthesia student ☐
B. Postgraduate anaesthesia student ☐
C. Registered clinical officer anaesthetist ☐
D. Consultant anaesthesiologist ☐

Performance of lumbar spine ultrasound scan

Primary anaesthesia care provider performing ultrasound scan

A. Postgraduate anaesthesia student ☐
B. Consultant anaesthesiologist ☐

For A: What is your year of study?

☐ 1 ☐ 2 ☐ 3 ☐ 4

For B: How many years have you been in practice?

☐ 1-5 years
☐ 5-10 years
☐ >10 years

Palpability of anatomic landmarks

☐ Good (Both the iliac crests and spinal processes are easily palpable.)
☐ Moderate (Only one of either the iliac crests or spinal processes is palpable.)
☐ Poor (Neither iliac crests nor spinal processes are palpable.)

Intervertebral spaces located via ultrasound

☐ L3/4 only ☐ L4/5 only L3/4 ☐ and L4/5

Midline identified

Yes ☐ No ☐

Quality of ultrasound

☐ Good (Can visualize well defined vertebral bodies and the ligamentum flavum-dura complex.)

☐ Moderate (Can visualize the vertebral bodies and the ligamentum flavum-dura complex but only one is well defined.)

☐ Poor (Vertebral bodies and ligamentum flavum-dura complex not well defined.)

Vertebral level at which the palpated tuffier’s line crosses ………..

Skin to subarachnoid space distance ……………………….cm

Performance of LP for spinal anaesthesia

Primary anaesthesia care provider performing the LP for spinal anaesthesia

A. Postgraduate anaesthesia student ☐

B. Consultant anaesthesiologists ☐

For A: What is the year of study?

1 ☐ 2 ☐ 3 ☐ 4 ☐

For B: How many years of practice?

☐ 1-5 years

☐ 5-10 years

☐ >10 years

Type of spinal needle

☐ Cutting tip ☐ Pencil point

Spinal needle gauge………………

Level of puncture

☐ L3/4 ☐ L4/5

Number of needle redirections ☐ 0 ☐ 1-3 ☐ >3

Number of puncture attempts ☐ 0 ☐ 1-3 ☐ >3

Number of multilevel punctures ☐ 0 ☐ 1-3 ☐ >3

Traumatic (Bloody attempt)? ☐ Yes ☐ No

If yes, how many ……………….

Did the patient experience any paresthesia during puncture?

☐ Yes ☐ No

If yes, how many times ……………..

Free CSF flow on puncture ☐ Yes ☐ No

Skin to subarachnoid space measurement (ED-N) ………………..cm

Failed attempt under U/S guidance (> 5 puncture attempts)

☐ Yes ☐ No

If yes, what is the final management of failed attempt under ultrasound guidance?

- Spinal anaesthesia using landmark palpation as a guide ☐
- General anaesthesia ☐

Other complications observed

- Cardiac arrest ☐
- Hypotension ☐
- Failed or patchy block ☐
- Post dural puncture headache ☐
- Others…………………………………………..

Interventions for the complications?

- Administration of vasopressor ☐
- Cardiac compressions ☐
- Intubation and mechanical ventilation ☐
- Others ……………………………….

Have you had previous spinal anaesthesia?

☐ Yes ☐ No

If yes, was this spinal anaesthesia experience better, worse or the same as last time

☐ Better ☐ Same ☐ Worse

Appendix II: Consent Information and Explanation for Patient/Next of Kin

Study Title: **THE EFFECTIVENESS OF PRE-PUNCTURE LUMBAR SPINE ULTRASOUND SCANNING IN SPINAL ANAESTHESIA FOR CAESAREAN SECTION**

Study Site: Kenyatta National Hospital and Naivasha level 5 Hospital maternity theatres.

Kindly read the information below before deciding to participate in this study

Background

My name is Consolata Njoki Kinuthia. I am an anaesthesia postgraduate student at the University of Nairobi. I am conducting a study on lumbar spine ultrasound as a guide for performing spinal anaesthesia in obstetric patients.

Purpose of the study

Spinal anaesthesia is a form of regional anaesthesia administered to a patient mostly for surgeries below the level of the umbilicus. A spinal needle is introduced through your back and advanced until the subarachnoid space. This space contains cerebrospinal fluid which surrounds the spinal cord and spinal nerves. A local anaesthetic is then injected into this space to cause anaesthesia of the lower part of the body. Lumbar spine ultrasound allows the identification of the space through which the spinal needle is introduced. It also gives an estimate of the distance from skin to subarachnoid space hence aiding in performance of this procedure.

Voluntary participation

Participation in this study is voluntary. You will be required to sign a consent form before participating. Participation in this study will not alter your/your patient's treatment plan. No payments will be made due to your participation in this study.

Risks

There are risks associated with spinal anaesthesia such as hypotension and rarely, allergic reaction to local anaesthetics, need for repeated attempts and high spinal. The anaesthesia team is well trained to handle such cases should they arise.

Right of withdrawal

You are free to withdraw from the study at any time and without giving any reason.

Confidentiality

Any information obtained in this study will be treated with confidentiality. Patient's names will not be used.

Results

The results of this study will be shared with the KNH/UoN department, experts and through conferences and publications. Your information will be kept confidential

Cost and Compensation

You will not incur any extra cost by participating in this study and no monetary benefit will be awarded.

Ethics and Research committee

In case of any concerns about this study you can contact the KNH/UoN Ethics and Research committee through the following contacts:

KNH-UON Secretariat

KNH/UoN ERC

College of Health Sciences

P.O. BOX 19676-00202

NAIROBI

Tel: +254 (020) 27263009 Ext 44355 Email: uonknh erc@uonbi.ac.ke

Appendix III: Consent form

Statement of consent by patient/next of kin

I………………………………………….. Of ………………………………………… or I……………………………………… next of kin to …………………………………….. hereby give consent to participate in the study on the effectiveness of pre-puncture lumbar spine ultrasound scanning in spinal anaesthesia for caesarean section at Kenyatta National Hospital and Naivasha level 5 Hospital.

I have been given the information on the study and informed that the procedure used is safe and will not compromise the safety of the patient. I have understood and had an opportunity to have any concerns addressed.

I have freedom to withdraw from this study at any given time.

Signed………………………………..…………….. Date………………………………..

I confirm that I have explained to the patient/ next of kin the purpose, nature and benefits of the study to the best of my knowledge.

Signed………………………………..…………….. Date………………………………..

FOMU YA MAKUBALIANO YA KUJIUNGA NA UTAFITI

Fomu hii inatoa mwaliko ya kujiunga na utafiti kwa akina mama wajawazito wanaohudumiwa katika hospitali ya kitaifa ya Kenyatta.

Mada ya utafiti huu ni:

PRE-PUNCTURE LUMBAR SPINE ULTRASOUND FOR OBSTETRIC SPINAL ANAESTHESIA.

Jina langu ni Daktari Consolata Njoki Kinuthia. Mwanafunzi wa shahada ya uzamili ya anaesthesia katika chuo kikuu cha Nairobi.

Lengo la utafiti huu ni kutumia mashine ya ultrasound kubaini nafasi inapopitia sindano ya uti wa mgongo kuanzia kwenye ngozi hadi nafasi inayozingira uti wa mgongo ambapo madawa ya nusukaputi huwekwa ili mgonjwa asihisi maumivu upasuaji unapofanyika.

Kwa idhini yako kupitia kuweka sahihi kwamba umeelewa fika lengo na madhara ya utafiti huu, utachaguliwa kwa njia nasibu kushiriki. Kusajiliwa ni kwa hiari yako na hakuna mapato yoyote utakayopata kwa kushiriki katika utafiti huu.

Madhara yanayohusishwa na anesthesia ya uti wa mgongo ni kama vile upungufu wa shinikizo la damu, mzio wa dawa za nusukaputi na kudungwa sindano zaidi ya mara moja kwenye uti wa mgongo. Madaktari wetu wana ujuzi na uwezo wa kuyamudu madhara yoyote yanayoambatana na utafiti huu ili kuhakikisha usalama wako.

Habari zote tutakazopata kutoka kwa washikiriki wa utafiti huu zitawekwa kwa usiri ili kulinda hadhi ya wahusika. Majina ya washirika hayataandikwa popote kwenye utafiti huu.

Baada ya uchambuzi wa habari zote nitakazopata kutokana na utafiti huu, nitachapisha matokeo katika kitabu maalum kitakachohifadhiwa na Chuo Kikuu cha Nairobi.

Kwa maswali yoyote au maelezo zaidi kuhusu utafiti huu, tafadhali yaelekeze kwa KNH-ERC, Hospitali ya kitaifa ya Kenyatta, Sanduku la Posta 20723, Nairobi. Nambari ya simu: 2726300-9.

FOMU YA IDHINI

Nambari ya usajili……………..

Mimi………………kutoka…………………. Ama jamaa wa karibu wa……………………. Nimekubali kushiriki katika utafiti wa ‘Pre-puncture lumbar spine ultrasound for obstetric spinal anaesthesia.’

Ninaelewa yakwamba uchunguzi utafanyika bila madhara yoyote kwa mgonjwa.

Nina uhuru wa kujiuzulu kutoka kwa utafiti huu wakati wowote ule.

Sahihi……………………………….………. Tarehe……………….………………

Ninadhibitisha yakwamba nimemweleza mgonjwa kwa ukamilifu kuhusu utafiti huu na amekubali bila kushurutishwa.

Sahihi……………………………….………. Tarehe……………….………………

Appendix IV : Spinal Anaesthesia Protocol Kenyatta National Hospital Maternity Theatre

1. Know the indications and contra-indications.
2. Inform the patient what you wish to do and have her co-operation.
3. Inform the rest of the team in theatre so you can be assisted appropriately.
4. Insert a good gauge intravenous cannula (Gauge 20 or larger).
5. Pre-load with ½ -1L Normal saline / Hartmann's over 30- 60minutes.
6. Install your monitors (pulse, respiration, SPO2, BP, ECG) and take baseline readings.
7. Position the patient either sitting or lateral knee-chest. Make the patient comfortable.
8. Open your spinal tray, clean the site and drape.

Spinal Tray should contain:-

a) Sterile towels for draping the patient
b) 2 gulley pots for holding cleaning solutions
c) Appropriate spinal needle (with introducer where required)
d) 2 syringes & needles
i. 5cc for infiltration of L.A to the site
ii. 2cc for administering the spinal medication
iii. Sterile gauze pads for cleaning & dressing

9. Reconfirm the position of the patient (knee chest)
10. Identify the site: mid-line L3-4/ 4-5 & administer 3ml of 1-2% lignocaine using a gauge 21 needle to maximum depth. Withdraw the needle as you continue to administer L.A and raise a skin wheal.
11. Give 1-2 minutes for the L.A to take effect as you re-assure & position patient (if administered well, this usually covers one vertebra above and below, should you need to alter position of lumbar puncture)
12. While waiting for L.A to take effect, prepare your appropriate drug. You must have decided whether using plain or heavy L.A

a) Remember Heavy (hyperbaric) L.A is position dependent. The patient must be appropriately positioned after injection to allow desired distribution.
b) **Bupivacaine** is usually 0.5% concentration. Most patients will require between 7.5mg (1.5mls) to 10mg (2mls).

c) Obstetric patients are more sensitive and will require between 7.5mg (1.5mls) to 10mg (2mls). Aim for a block up to T6. Test and record level of block.

d) Additive: **25mcg Fentanyl** (0.5mls) is a useful additive to prevent the discomfort of gut handling during C/S etc. This must still make up the total volume of 2-2.5 mls of drug injected into the spinal canal. Other drugs have been used as additives but it's best to avoid them unless you have been trained to use them. The haphazard use of additives into the CSF may have disastrous results.

e) Remember, for C/S the volume and position are critical to achieve a good or disastrous spinal block.

13. Confirm the L.A has taken effect and note level/site of the block.
    Insert the spinal needle. Usually there is a sudden give when the needle goes through the dura. Withdraw the stylet and check for CSF flow. Do not allow unnecessary drainage of C.S.F. Use the stylet to stop the flow temporarily, if you cannot administer the spinal drug immediately.
14. Administer the drug, dress the puncture site and position the patient appropriately to allow planned distribution of drugs. Rapid positioning after administration is critical if the drug used is hyperbaric (heavy).
15. Start your post-spinal monitoring & make adjustments accordingly. It is recommended to repeat blood pressure readings at 1 minute intervals. You will need to respond rapidly to the initial changes in pulse and blood pressure. Ask the patient to inform you immediately if nausea occurs. Nausea in spinal anaesthesia is most likely due to hypotension. It is an early warning sign that you must not ignore.
16. Test the level of the block. The tilt of the bed may have to be adjusted if using hyperbaric local anaesthetic to change drug distribution. This manipulation may only work within the 1st 10-20mins after administration of the L.A into the C.S.F.
17. **Post-operative pain management** -Intramuscular pethidine 1mg/kg 4-6hourly for 24 hours or subcutaneous morphine 10mg 4-6hrly for 24hours.
    - Olfen suppositories (or equivalent) stat and 12 hourly for 48 hours, then oral medications.
    -Intravenous paracetamol 1g intra-operatively then 6 hourly for 24 hours may be beneficial
    - Follow up visit, within 24hours.

18. **Critical observation**

a) Pulse – symptomatic bradycardia – Atropine 0.1 -0.6mg

b) SPO_2 ≤90% - Increase the O_2 flow by mask or Nasal prongs.

c) BP –symptomatic Hypotension

- Ephedrine -5mg-10mg PRN (you may occasionally need an infusion)
- Aramine
- Adrenaline (1:10,000 and 1:200,000)
- Phenylephrine

d) Respiration –falling respiratory rate (usually temporary)

- May be due to hypotension
    - Treat hypotension
    - Give oxygen
    - Assist with respiration briefly if required
    - Reassure

e) **Total Spinal Anaesthesia**

i. Convulsions /loss of consciousness

ii. Respiratory failure

iii. Cardiovascular collapse

Management includes: Intubate, ventilate, cardiac massage, vasopressors, anticonvulsants till vital signs stabilize.

f) **Post-dural puncture headaches**

These may occur post operatively (but rarely). They are worse when standing and relieved by lying down.

<u>Management</u>

i. Bed rest

ii. Plenty of fluids (intravenous and/or oral) including caffeine

iii. NSAIDs and Betapyn (codeine, caffeine, paracetamol & Doxylamine)

iv. Epidural blood patch as a last resort (when conservative management fails)

19. Post-Operative care

–monitor BP ¼ hourly for 2hours.

Positioning –make patient comfortable with pillow under the head.