LUMBAR SUBARACHNOID DRAINS FOR CSF DRAINAGE IN PITUITARY SURGERY: TECHNICAL DIFFICULTIES AND COMPLICATIONS – AN OBSERVATIONAL STUDY

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE M. D. DEGREE (BRANCH X) ANAESTHESIOLOGY EXAMINATION OF THE TAMIL NADU DR. M. G. R. MEDICAL UNIVERSITY, TO BE CONDUCTED IN MAY 2018

DECLARATION

I hereby declare that this dissertation titled entitled **'Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – An observational study'** was prepared by me in partial fulfilment of requirement of the regulations for the award of degree MD Anaesthesiology of The Tamil Nadu Dr. M. G. R. University, Chennai. This has not formed the basis for the award of any degree to me before and I have not submitted this to any other university previously.

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This is to certify that the dissertation entitled, **'Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – An observational study'** is a bonafide work of **Dr. Mridul Susy Koshy** carried out under my guidance towards the M.D Anaesthesiology Examination, of the Tamil Nadu M.G.R University, Chennai to be conducted in May 2018.

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CERTIFICATE

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Dr. Anna Pulimood

Principal

Christian Medical College and Hospital,

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Mridul Susy Koshy, Employment Number: 29586, PG Registrar / Anaesthesia / Unit 3, Dr. Georgene Singh Employment Number: 28474, Dr. Ramamani Mariappan, Professor, Employment Number: 50916, Department of Anaesthesia. Mrs. Mahasampath Gowri, Senior Demonstrator, Department of Biostatistics.

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I enclose the following documents:-

1. Institutional Review Board approval 2. Agreement

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With best wishes,

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Dear Dr. Mridul Susy Koshy,

The Institutional Review Board (Blue, Research and Ethics Committee) of the Christian Medical College, Vellore, reviewed and discussed your project titled "Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – An observational study" on February 01st 2017.

The Committee reviewed the following documents:

1. IRB Application format
2. Patient information sheets and Consent forms (English, Tamil, Hindi, Telugu)
3. Proforma
4. No. of documents 1 – 3.

The following Institutional Review Board (Blue, Research & Ethics Committee) members were present at the meeting held on February 01st 2017 in the Jacob Chandy Hall, Paul Brand Building, Christian Medical College, Vellore 632002.

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Dr. Sathish Kumar	MBBS, MD, DCH	Professor, Child Health, CMC, Vellore	Internal, Clinician

We approve the project to be conducted as presented.

Kindly provide the total number of patients enrolled in your study and the total number of withdrawals for the study entitled: "Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – An observational study." on a monthly basis. Please send copies of this to the Research Office (research@cmcvellore.ac.in).

Fluid Grant Allocation:

A sum of Rs. 42,515/- INR (Rupees Forty two Thousand five hundred and fifteen only) will be granted for 8 months.

Yours sincerely,

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Secretary (Ethics Committee)
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Finally and most importantly, I would like to express my sincere gratitude to all the patients who participated in this study.

Abstract

Title: Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – An observational study

Context: Lumbar drains are commonly used for intra- operative CSF (cerebrospinal fluid) diversion, both as a prophylactic measure and therapeutic measure in the presence of CSF leak in trans-nasal trans-sphenoidal pituitary surgery. The documented risk of complication with the use of lumbar drains is 8%. Although generally considered safe, lumbar drain insertion increases the length of hospitalization, causes major and minor complications such as headache, backache, meningitis, radiculopathy, retained catheter fragments and patient discomfort. It has been shown that perioperative lumbar drain insertion for CSF diversion decreases the overall risk of post-operative CSF leaks. The studies that have been performed, regularly use the specifically designed lumbar drain kit such as the Codman lumbar drain kit. Owing to the unavailability and unaffordability of the same in our setting, we regularly use the epidural kit for placing lumbar drains. This is often associated with difficulty in CSF drainage.

Since the diversion of CSF, is the key to successful surgery, we would like to see if the use of epidural kit for this purpose is associated with a higher incidence of difficult placement and unsuccessful CSF drainage and complications.

Aim:

To study the technical difficulties faced during lumbar subarachnoid drain placement and the complications associated with the lumbar drain.

Objectives:

1. To assess the incidence of complications associated with pre-operative lumbar drain placement in endoscopic pituitary surgery

2. To study the incidences of difficulties observed with lumbar CSF drain catheter placement with the epidural catheter set.

3. To study the incidence of difficulty in intra-operative CSF drainage following successful lumbar drain placement with the epidural catheter set.

4. To study the manoeuvres attempted to improve intra-operative CSF drainage.

Study Design: Prospective observational study

Materials and Methods: All Neurosurgery unit 1 patients, who underwent trans-nasal trans- sphenoidal resection of pituitary tumours, and required pre-operative lumbar drain placement as planned by the neurosurgeon, were recruited for the study. The department of Neurosurgery unit 2, does not routinely place lumbar drains as per their protocol for trans-nasal trans-sphenoidal surgery. A detailed patient information sheet was provided to the subjects and the primary investigator explained the technique and need for placement of the lumbar drain. Informed consent was then obtained from the subject. The technique of lumbar drain placement was decided upon by the concerned anaesthesiologist at the time of surgery. The other intra-operative details were also filled by the concerned anaesthesiologist in the proforma sheet. The patient was followed up post-operatively by the primary investigator, up to one day after completion of the surgery. The incidence of complications of lumbar drain placement, difficulty in placement, difficulty in drainage of CSF and the manoeuvres to improve the lumbar CSF drainage were assessed. The volume of CSF drained, presence or absence of CSF leak

and the operative conditions, as assessed by the surgeon, were also noted. The data was analysed to arrive at the results.

Conclusion: Although lumbar subarachnoid drain placement for pituitary surgery is associated with only minimal complications, there is an unacceptably high rate of difficulties in placement and lumbar subarachnoid drain failure rates.

Keywords: lumbar subarachnoid drains, pituitary surgery, epidural kit, technical difficulties, complications.

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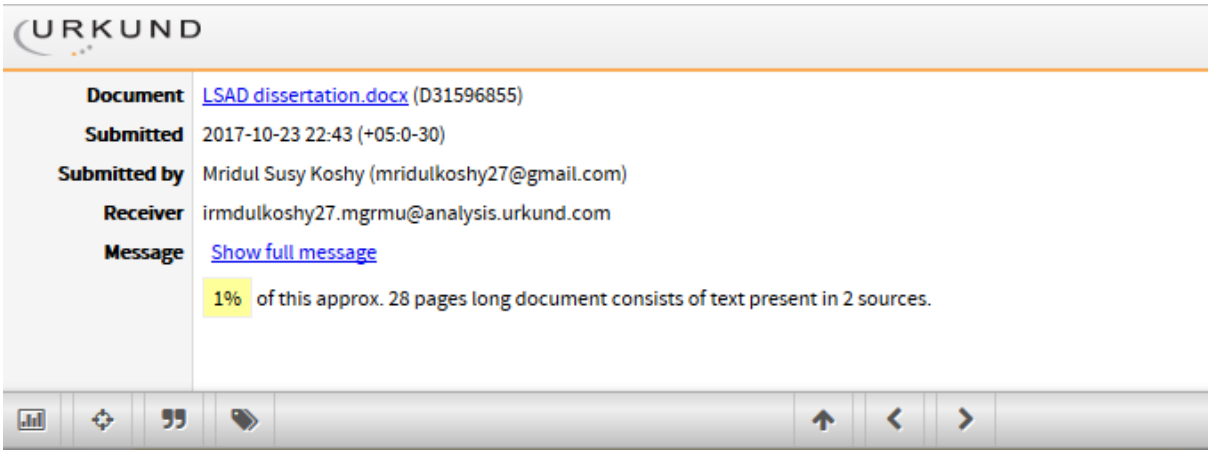
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CONTENTS

INTRODUCTION

INTRODUCTION

Pituitary tumours are the most common primary tumours of the CNS. The treatment of choice for these pituitary macro-adenomas is resection via the trans-nasal trans-sphenoidal approach. The leading cause of morbidity following trans-nasal trans-sphenoidal surgery is the presence of persistent cerebrospinal fluid leakage. Macro-adenomas, particularly those with suprasellar extension, have been found to have a higher incidence of post-operative CSF leak than micro-adenomas. The placement of a lumbar drain just before trans-nasal trans-sphenoidal pituitary surgery for the intra-operative drainage of CSF, significantly reduces the incidence of intra-operative leaks by 41%.The standard lumbar drain used is the Codman's lumbar drainage catheter kit. In our setting, due to unavailability and the prohibitive cost, it has been the usual practice to use epidural kits. The placement of a lumbar drain is an invasive procedure with a 5% minor and a 3% major complication rate. The complications that usually occur are headache, meningitis, cellulitis and retained catheter fragments.

Accidental over drainage also contributes to complications like pneumocephalus, subdural hemorrhage, neurological decline and uncal herniation. Errors that can occur when multiple patient-care transfers are involved for example, unintended disconnection, inadvertent opening and over drainage are known to occur with the use of lumbar drains.

However, the current literature does not mention any studies performed on the problems associated with difficulties faced in insertion or intra-operative CSF drainage/flow using an epidural kit for lumbar drain placement instead of using the standard Codman's lumbar kit. Moreover, since the lumbar drain is removed at the end of the procedure if there is no CSF leak, we would like to compare the complication rate with other studies, where lumbar drain has been used for a longer duration.

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REVIEW OF LITERATURE

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Introduction:

The trans-nasal trans-sphenoidal approach for excision of pituitary tumours is now a safe and effective mode of pituitary tumour resection. Perioperative cerebrospinal fluid diversion by lumbar subarachnoid drains can be used as a prophylactic measure or as a first line of treatment for cerebrospinal fluid rhinorrhoea following trans-nasal trans-sphenoidal surgery. The placement of the lumbar drain in the operation theatre has always been done by the anaesthesiologist, either preoperatively under local anaesthesia or after the induction of anaesthesia. It is usually placed in the lumbar spine level and the catheter is threaded wither upwards or downwards to obtain a steady flow of cerebrospinal fluid.

1. HISTORY

Hippocrates (460-370BC) first described cerebrospinal fluid as "water surrounding the brain." Galen, (129-200AD) later discovered it is present in the ventricles of the brain. In 1744, Swedenborg found that cerebrospinal fluid is secreted from the roof of the fourth ventricle and flows to the medulla oblongata and spinal cord. Von Haller identified that the fluid in the brain was in fact being secreted into the ventricles. Faivre in 1854 and Cushing in 1914, suggested that cerebrospinal fluid is secreted by the choroid plexuses. Rougemont and colleagues in 1960 presented experimental evidence to show that cerebrospinal fluid is indeed secreted by the choroid plexuses. They also went ahead to prove that cerebrospinal fluid was not an ultra-filtrate of plasma. Several other imminent scientists like Willis, Cushing, Mestrezat and Magendie made further progress in research on cerebrospinal fluid(1).

Superficial intracranial fluid was first evacuated in children with hydrocephalus in the tenth century by Abulkassim Al Zahrawi. LeCat published his findings on ventricular puncture in 1744.However, it was only in the year 1881 that Wernicke performed an external cerebrospinal drainage and sterile ventricular puncture(2).

Many authors credit the German internist, Heinrich Irenaeus Quincke, with the introduction of the lumbar puncture procedure in the year 1891. However, some other authors also mention the American neurologist, James Leonard Corning, to have first performed the lumbar puncture procedure using bird quills in 1885. In 1898, Dr. Bier described the first case of post dural puncture headache when, due to the lack of the correctly fitting syringe, there was continuous cerebrospinal fluid drainage from the dural puncture site.

2. ANATOMY OF THE SPINE

The axial skeleton consists of 33 vertebrae - seven cervical, twelve thoracic, five lumbar, five fused sacral and four fused coccygeal vertebrae. The cervical and lumbar spine regions are convex forward and hence form anatomical lordotic curves. The thoracic spine region is concave forward and hence forms an anatomical kyphotic curve. The lumbar lordotic curve is more pronounced in females as compared to males. The lumbar curvature begins at the middle of the lower thoracic vertebrae and terminates at the sacrovertebral angle.

There are various ligaments which play a vital role in supporting and aiding the movements of the spinal column. These include the anterior longitudinal ligament, posterior longitudinal ligament, inter-spinous ligament and the supraspinous ligament.

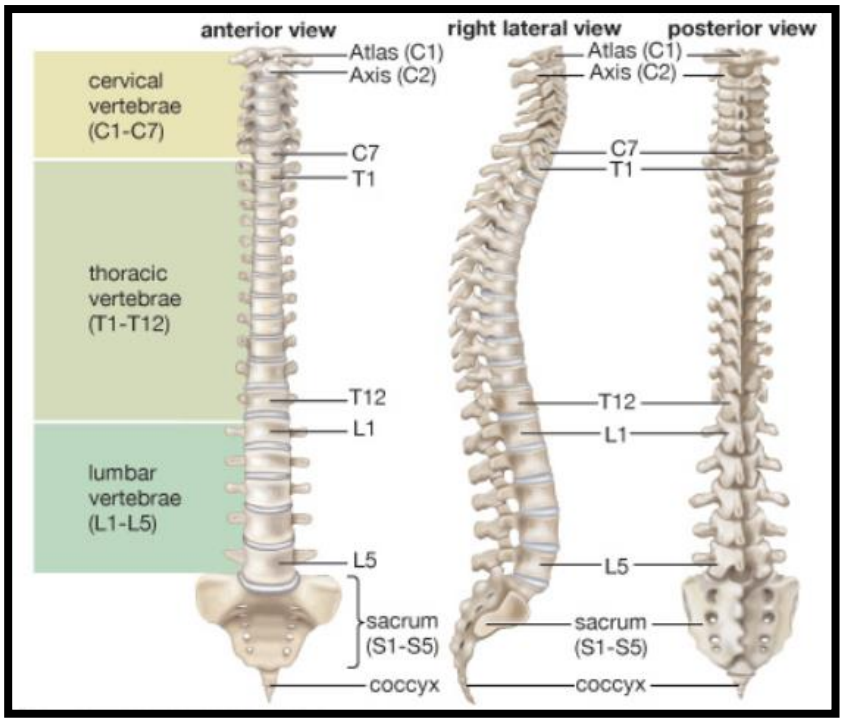


Figure 1 – Anatomy of the spine

3. ANATOMY OF THE SPINAL CORD

The spinal cord extends from the brainstem up to the filum terminale and cauda equina in the conus medullaris. The spinal cord ends at the lower border of the L1 vertebra in adults and at the L3 vertebra in children. However, the dural sac ends at the S2 vertebra for adults and may be lower in children. The spinal cord is covered by the meninges consisting of: the pia mater, the arachnoid mater and the dura mater. The subarachnoid space or intrathecal space lies between the pia mater and the arachnoid mater. The subarachnoid space is bathed in cerebrospinal fluid (CSF). The epidural space surrounds the dura mater and extends from the brainstem to the sacral hiatus. The ligamentum flavum lies posterior to the epidural space and also extends from the brainstem to the

sacral hiatus. The ligamentum flavum varies in respect to its thickness, depth from the skin and the distance from the dura mater, at various points in the vertebral canal(3).

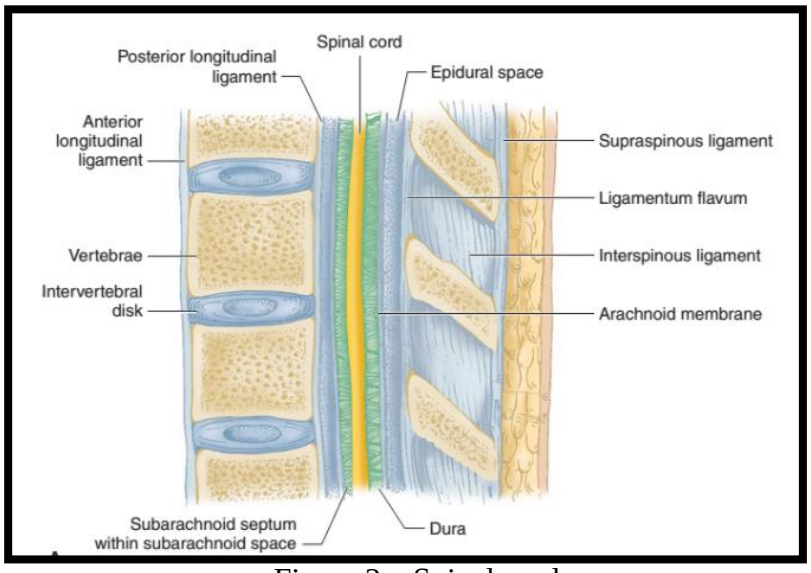


Figure 2 – Spinal cord

4. CEREBROSPINAL FLUID

Cerebrospinal fluid (CSF) is colourless and constitutes 8% of the total volume of the cranial vault[i]. It is present within the subarachnoid space, the four ventricles of the brain and the central canal of the spinal cord. It provides protection to the central nervous system by cushioning it from trauma(4).It also regulates the pH and electrolytes, supplies nutrients and carries away excretory products(5).

The cerebrospinal fluid is formed by the choroid plexuses, ependymal cells lining the ventricles and by the leakage of fluid into the perivascular spaces around the cerebral vessels. The normal rate of cerebrospinal fluid production is 0.4 ml/min/gm of tissue(1) or 21 ml/hr or 500 ml/day(6). However, the total cerebrospinal fluid in the body is 150ml and out of which, 30-80ml of the cerebrospinal fluid is present in the subarachnoid space from the eleventh thoracic space downward(3). Thus the entire volume of cerebrospinal fluid is completely replace three to four times in a day. The cerebrospinal fluid volume is

variable between patients and is dependent on the weight and body habitus of the individual. Therefore, patients with a higher body mass index tend to have a lesser volume of cerebrospinal fluid(3).The rate of cerebrospinal fluid production has been found to decrease with aging(7).

The major components of cerebrospinal fluid are glucose, protein, sodium chloride and water. As a result, cerebrospinal fluid is isotonic with plasma.

The flow of cerebrospinal fluid is from the lateral ventricles into the third ventricle through the Foramina of Monro, into fourth ventricle through the Aqueduct of Sylvius and into the cisterna magna through the Foramen of Magendie and Foramina of Luschka. From the cisterna magna, the cerebrospinal fluid flows into the subarachnoid space, around the brain and spinal cord and is finally absorbed by the arachnoid granulations which are present over the cerebral hemispheres.

The process of absorption occurs by translocation of cerebrospinal fluid from the arachnoid granulations into the cerebral venous sinuses. Small volumes of cerebrospinal fluid are also absorbed by the meningeal lymphatics and at the nerve root sleeves. Due to the absence of lymphatics in the spinal cord and the brain, the absorption of cerebrospinal fluid also helps to return the interstitial and perivascular proteins back to the blood(6).

The normal intracranial pressure is less than 10-15mmHg(8). It is the supra-tentorial cerebrospinal pressure measured over the cerebral cortex or within the lateral ventricles(6).

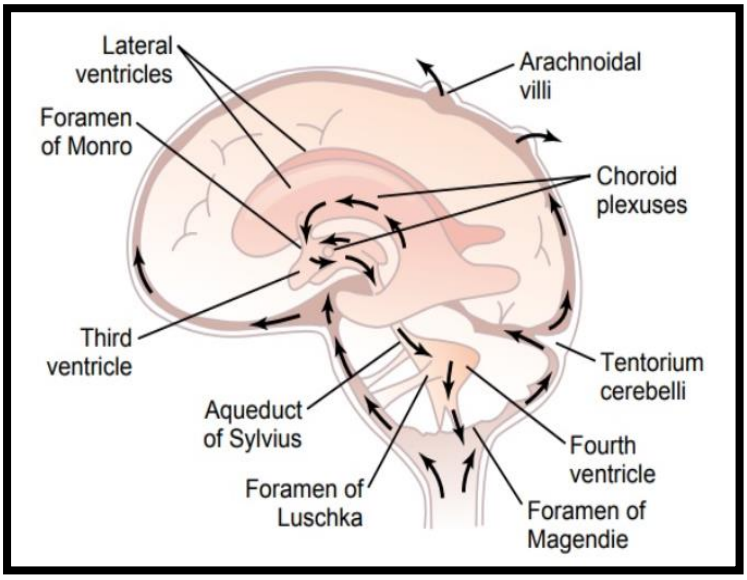


Figure 3 – Cerebrospinal fluid flow

5. LUMBAR SUBARACHNOID DRAIN (LSAD)

INDICATIONS FOR PLACEMENT OF LSAD:

- Access for intrathecal fluorescein administration
- Access for obtaining cerebrospinal fluid samples
- Evaluation and treatment for normal pressure hydrocephalus (2) (9)
- Treatment modality for bacterial meningitis (10) (11)
- Treatment modality for fungal meningitis (12)
- Treatment for dural defect in the cistern or ventricle causing a cerebrospinal fluid leak (13) (14) (15) (16)
- Prevention and treatment of cerebrospinal fluid fistula (17)
- As a diversion procedure for the treatment of cerebrospinal fluid rhinorrhoea (18) (19) (20)
- Prophylactically to prevent cerebrospinal fluid leak for pituitary surgery and during trans-nasal trans-sphenoidal surgeries (21) (22) (13) (23) (14) (24)

- Prophylactically to prevent spinal cord ischemia during thoracic endovascular aortic repair procedure (25)
- Preventive measure for aneurysmal subarachnoid haemorrhage (26) (27)
- Therapeutic measure for raised intracranial pressure (28) (29)

CONTRAINDICATIONS FOR LSAD PLACEMENT

Absolute contraindications:

- Patient's refusal to give consent for the procedure
- Bleeding disorder or coagulopathy
- Presence of significantly increased intracranial pressure
- Local skin infection at the intended site of injection
- Hypovolemic shock
- Allergy to any material or drug to be used for the procedure

Relative contraindications:

- Septicaemia
- Anticoagulation or thromboprophylaxis
- Demyelinating nerve disease
- Pre-existing nerve deficits
- Stenotic valve disease or fixed cardiac output diseases
- Spine deformities
- Stenosis of the spinal canal
- Obstruction of the left ventricular outflow tract
- Previous spine surgery

- Lack of co-operation from the patient

ANATOMY RELEVANT TO THE LUMBAR SPACE

The lumbar spine is usually preferred for the placement of the lumbar drain. The ideal lumbar level is L3-L4 or L4-L5. The lumbar vertebrae have large, kidney shaped bodies and a triangular shaped vertebral foramen. The vertebrae have shallow superior notches, thick pedicles and thin transverse processes. The lumbar laminae are broad, short and do not overlap each other unlike the thoracic vertebrae. The spinous processes are almost horizontally angulated. The intervertebral space is increased by flexion of the spine, which is taken into consideration while positioning a patient for placement of a lumbar subarachnoid drain (30).

PRE-PROCEDURAL PREPARATION

- Confirm and verify the indication for the procedure
- Ensure there are no contraindications to performing the procedure
- Explain the procedure and its complications, in full detail, to the patient and his/her caregiver and obtain informed consent for the procedure
- History given by the patient should be ascertained
- Thorough clinical examination of the patient should be performed – with stress on the neurological examination
- Patients with symptoms associated with cognition were made to undergo the Folstein Mini Mental Status Examination
- Review the CT(computer tomography) or MRI(magnetic resonance imaging) reports for signs of a mass or features of raised intracranial pressure

- MRI to be obtained for all patients with a posterior fossa mass
- Check to see if the fourth ventricle and quadrigeminal cistern are visible – especially in cases of bacterial meningitis
- It is ideal to obtain a CT scan on all patients prior to placement of a lumbar drain – especially if the patient has features of raised intracranial pressure (31) like new onset seizures, focal neurological deficits, episodes of unconsciousness, papilledema and difficulty in visualising the optic fundus
- correction of any deranged bleeding parameters to within normal limits
- baseline investigations should be within the normal limits

TIMIING

As there is no consensus or guidelines currently present for the use of lumbar drains in trans-sphenoidal surgery, various authors have mentioned different timings regarding the same (24).

Some authors recommend the preoperative placement of the lumbar drain only in cases of large encephaloceles, meningiomas, raised intracranial pressure with anticipated patient comorbidity and anticipated high volume postoperative cerebrospinal fluid leak (32) (33). Whereas some authors favour the use of preoperative lumbar drains to improve the surgical access in cases of pituitary macro-adenomas when there is a bottle-neck type of constriction at the diaphragma sellae, small sellae and to aid in visualisation of the suprasellar structures (34). The routine preoperative used of lumbar drains for all cases is also practised by some authors to reduce the occurrence of intraoperative cerebrospinal fluid leaks (23). The placement of lumbar drains have been done in the postoperative period as well in the setting of a postoperative cerebrospinal leak.

Among the studies where the lumbar drains have been placed preoperatively, there is usually no mention of whether it was performed on an intubated patient in the operating room or a non-intubated patient in a preoperative area.

However, one study has mentioned the placement of the lumbar drain in an intubated patient, prior to commencement of the surgery (23). Another study has mentioned the placement of the lumbar drain during the surgical procedure (35).

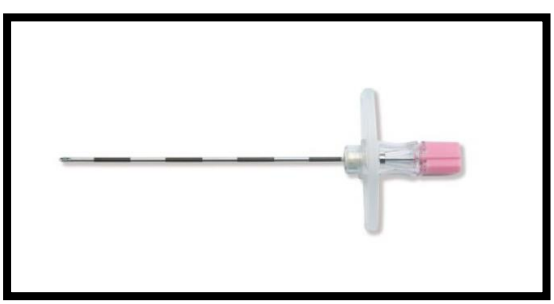
As the placement of a lumbar drain is considered to be a painful procedure, most surgeons prefer to place them after the patient has been anaesthetised and intubated. However, the placement of lumbar drains in an anaesthetised and intubated patient can cause late detection of a nerve root injury or spinal haematoma.

TECHNIQUE

PREPARATION:

- Ensure that informed consent has been taken
- Resuscitation drugs and equipment must be kept ready and available
- Prophylactic antibiotic should be administered – preferably intravenous cefazolin
- Monitoring with pulse oximetry, electrocardiogram, non-invasive blood pressure and the presence of adequate intravenous access must be ensured
- Pre-prepared sterile lumbar drain pack should have all the necessary equipment – drapes, towels, sterilizing liquid, syringes with needles, local anaesthetic for skin infiltration and appropriate lumbar puncture needle
- Needle –

- The Tuohy 16G or 18G needles are most commonly used for placement of a lumbar drain
- The needle tips are blunt and have a 15 to 30 degree curvature which is termed as the ‘Hubner’ tip.
- The needle tip is designed in such a way to prevent accidental dural puncture and to ensure that the catheter is guided in the cephalad direction.
- The needle shaft is 8cm long and is demarcated in 1cm intervals, so as to identify the depth of insertion.



Figures 4 and 5 – Tuohy needle

- Catheter –
  - Most authors mention the use of Medtronic catheters or Codman catheters for the lumbar drain
  - Codman catheter :
    - It is 80cm long, made from silicone and comes with a pre-coiled guidewire.
    - The silicone body is pliable and ensures less trauma to the tissues.
    - The presence of the guidewire makes it easier to use and manoeuvre.
    - The guidewire is coated with lubricant, which prevents it from bunching up while being removed from the catheter.

- The catheter has large diameter holes which optimise the drainage of cerebrospinal fluid while reducing the chances of occlusion.
- The catheter is also radio-opaque due to the use of barium.
- The newer Codman catheters also come with the added advantage of having dual antibiotics impregnated into the silicone material.
- The antibiotics added are rifampicin and clindamycin
- The cost of the pre-packed Codman catheter and the lumbar drainage kit is Rupees 9,352. (36).
- Studies have shown silicone catheters to be superior to the routinely used nylon catheters (17).

➢ Medtronic catheter :

- The catheter is translucent with a radio-opaque barium line running along its length.
- It is made of soft, pliable silicone which reduces trauma to the tissues.
- It has markings at 1cm intervals and large diameter flow holes to prevent occlusion of the catheter.
- The silicone material is impregnated with dual antibiotics to prevent bacterial colonization in the catheter.
- The antibiotics used are rifampicin and minocycline.
- The cost of the Medtronic lumbar drain pre-packed kit is Rupees 7,128 (37).
- Studies show that the antibiotic embedded silicone catheters have lesser infection rates than the routinely used catheters (38).

- B-Braun and Portex catheters :
    - These are pre-packed epidural kits which are routinely used in most centres in India to perform lumbar drain procedures.
    - These catheters are made of nylon material.
    - The catheters are radio-opaque and have multiple orifices.
    - These catheters do not have guidewires or large diameter flow holes.
    - The cost of the Portex epidural kit is Rupees 1865.
    - The cost of the B-Braun epidural kit is Rupees 1100.
    - To complete the lumbar drain system, we also require a Romson I.V set and a Terumo Penpol transfer bag.
    - The Romson I.V set cost Rupees 53 and the Terumo Penpol transfer bag costs Rupees 81.

Figure 6 – Romson's IV set

Figure 7 - Terumo Penpol transfer bag

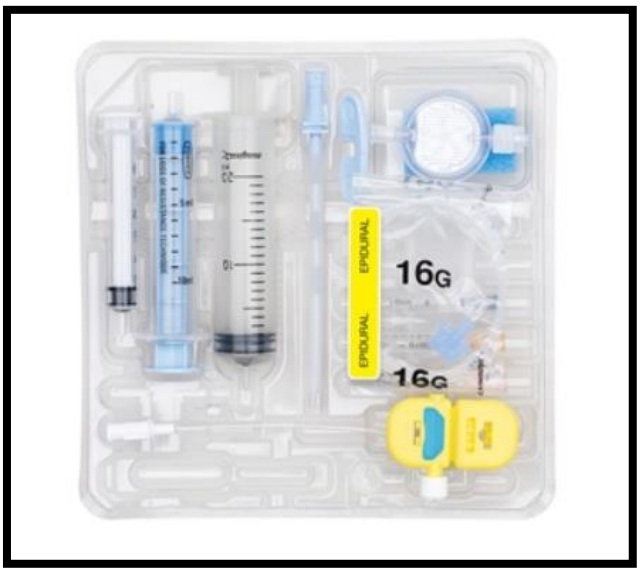


Figure 8 – Epidural kit

POSITION:

The lateral decubitus or sitting positions are employed to make the process of lumbar drainage easier. As the majority of lumbar drain placements are done in anaesthetised and intubated patients, the lateral decubitus position is preferred.

- Lateral decubitus position-
    - An un-anaesthetised and non-intubated patient in the lateral position is not dependent on an assistant. Sedatives can be administered to the patient under such circumstances.
    - However, in the case of performing the lumbar drain procedure on an anaesthetised and intubated patient, the presence of a trained anaesthesiology assistant is crucial.
    - The patient is made to lie, preferably in the left lateral decubitus position, for the ease in performing the procedure for a right handed anaesthetist.

- The patient is made to lie with the back as close to the edge and parallel to the edge of the operating table.
- The hip is flexed such that the knees are drawn up against the abdomen. The neck is also flexed.
- This position aims to increase the inter-vertebral spaces.
- This position may make it difficult to visualise the midline, especially in obese patients (3).

- Sitting position :
  - This position is used for un-anaesthetised and non-intubated patients only.
  - This position mandates the presence of a trained anaesthesiology assistant while performing the lumbar drain procedure.
  - Sedation is best avoided for patients in this position and hypotension is a common side effect.
  - Identification of the midline is made easier by this position and is especially helpful in obese patients or patients with scoliosis.
  - The patient is made to sit at the edge of the operating table, with his back to the anaesthetist who is to perform the procedure.
  - The patient can be made to rest his feet on a stool. The patient can also be flex his arms over a pillow.
  - The patient is then made to flex his neck and relax his shoulders (3).

Figure 9 – Sitting position

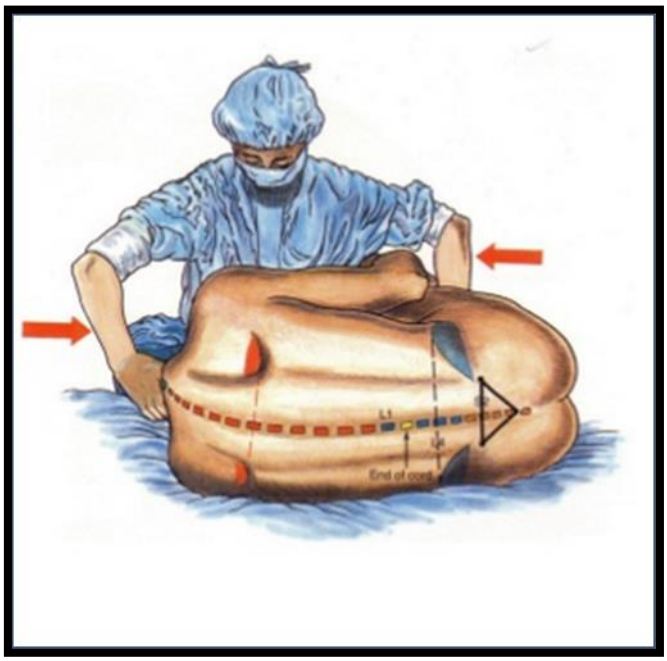


Figure 10 – Lateral position

PROJECTION AND PUNCTURE:

The procedure should be done in a sterile manner. Hence, the anaesthetist must wear a sterile gown, gloves and a face mask. The lumbar spine must be cleaned with a sterilizing solution like 10% povidone iodine or chlorhexidine and draped with a sterile drape. The hole in the centre of the sterile drape must be placed over the lumbar spine.

If the patient is un-anaesthetised, infiltrate the skin and subcutaneous tissue with 2% lignocaine before insertion of the needle. The best inter-vertebral space to place the lumbar drain is the L4-L5 space. However, the L3-L4 or L5-S1 spaces can be used as well. Performing the procedure at the L2-L3 intervertebral space or higher increases the chances of injury to the spinal cord. To identify the L4-L5 space, palpate for the highest point of the iliac crest. The imaginary line joining these two points is called 'Tuffier's line.' Tuffier's line passes through the L4 interbody or the L4-L5 interspace

The 16G or 18G Tuohy needle is inserted horizontally, at a 90 degree angle to the skin, such that it is parallel to the floor. This direction of insertion ensures that the needle enters at the superior aspect of the inferior spinous process. The bevel of the needle is held facing upwards (39).

There are various needle approaches that can be used for finding the epidural and subarachnoid spaces. The midline and paramedian approaches are commonly used while placing the lumbar drain. Various methods or techniques have been described to identify the epidural space. The most commonly used of these methods include the loss of resistance technique using either saline or air and the hanging drop technique.

MIDLINE APPROACH:

In the midline of the lumbar region, the depth from skin to the ligamentum flavum is almost 5-6 millimetres. Depending on whether the patient is thinly built or obese, this depth can

either be shorter or longer respectively. When performing the midline approach with the needle, the needle hub should be held between the thumb and index finger of the dominant hand, while the non-dominant hand can be placed on the patient's back. In a controlled and slow manner, the needle should be advanced with a 15 degree angulation towards the umbilicus. Once the needle has been passed through the supraspinous ligament and the inter-spinous ligament, the needle will rest firmly in the tissues without assistance. The stylet should be removed and the syringe should be attached to the needle hub. Some authors recommend to place the needle in the ligamentum flavum before attaching the syringe, as this helps to appreciate the epidural anatomy.

LOSS OF RESISTANCE TECHNIQUE:

If loss or resistance or hanging drop technique is attempted after passing through the inter-spinous ligament, there are increased chances of getting a positive result. This is due to the defects in the inter-spinous ligament and the false positive rates can be up to 30%. Loss of resistance technique can be performed using either saline or air in the syringe. If saline is the medium of choice for the loss of resistance technique, then constant and gentle pressure must be applied on the plunger of the syringe with the dominant hand. The non-dominant hand is used to advance the needle at the same time. If air is the medium of choice for the loss of resistance technique, then intermittent and gentle pressure must be applied on the plunger of the syringe. The medium used for the loss of resistance technique could also be a combination of 2ml of saline and a 0.25ml small air bubble. However, using air as a medium for the loss of resistance technique is considered less reliable than using other media in identifying the epidural space. It has also been known to cause venous embolism and pneumocephalus. The disadvantage of using saline as a medium for loss of resistance

technique would be the difficulty in differentiating it from cerebrospinal fluid after puncturing the dura mater (3). After identifying the epidural space, remove the syringe and replace the stylet. The needle should be advanced slowly in millimetres until a 'pop' is felt. The 'pop' felt is the needle passing through the dura and entering the subarachnoid space. Remove the stylet and check for the outflow of cerebrospinal fluid. If cerebrospinal fluid is noticed, thread in 10-15cm of the 80cm long catheter into the subarachnoid space through the Tuohy needle. The guidewire can be used if catheter insertion is found to be difficult.

Once the catheter is in place, it is secured in place with three 3-0 nylon sutures. The lumbar drain site dressing is done with a gauze piece, covered by a large transparent and occlusive Tegaderm dressing (40). Some authors also recommend tunnelling the catheter into the subcutaneous tissue in the attempt to secure it in place and facilitate long term cerebrospinal fluid drainage (41). Some authors have also used fluoroscopic guidance in difficult cases or when the catheter could not be advanced (42).

Once the catheter has been secured, it is then connected to the cerebrospinal fluid collection equipment. In institutes where the lumbar drain kits are unavailable, the epidural catheter is used and threaded through the Tuohy needle. The I.V set is then connected to the epidural catheter using the catheter adaptor. The Terumo Penpol transfer bag is in turn attached to the I.V set and acts as a collecting bag for the cerebrospinal fluid.

OTHER TECHNIQUES:

Many other techniques have been studied and used to overcome the difficulties and challenges associated with lumbar subarachnoid drainage.

- Guided technique – According to this technique, a 25 gauge Quincke needle is used to identify the subarachnoid space at the L3-L4 lumbar level. Once there is free flow of

cerebrospinal fluid from the Quincke needle, the 14 gauge Tuohy needle is introduced into the space. The subarachnoid space is identified by observing the direction and depth at which the Quincke needle achieved free flow of cerebrospinal fluid (43).

- Ultrasound guided – The use of ultrasound imaging of the lumbar spine and the target lumbar space, prior to performing the lumbar drain procedure, has been observed to reduce the technical difficulty involved in its placement and also improves the efficacy (44).

- Fluoroscopy guided – In cases where tapping the lumbar spaces were difficult or in obese patients, the use of fluoroscopy guided lumbar drain placement has been demonstrated to be an effective technique (42).

- Computer tomography guided

PARAMEDIAN APPROACH:

In this approach, the needle is inserted 1 to 2cm lateral to the inferior surface of the spinous process of the vertebral body above the target inter-vertebral space. It is advanced horizontally until it reaches the lamina. The needle is then directed medially and cephalad into the epidural space. All the other steps are the same as those mentioned in the midline approach.

6. CEREBROSPINAL FLUID DRAINAGE

Studies recommend the drainage of 20-60ml of cerebrospinal fluid in 20 ml increments, to reduce the intracranial pressure and prevent intraoperative and postoperative complications (24) (23). The recommended rate of drainage of cerebrospinal fluid is 5-10ml/hour or 120-360ml/day (40) (45) . The goal is to allow a controlled and low resistance drainage of cerebrospinal fluid in the immediate postoperative period. The drain has been recommended to be kept for 48-72 hours after the surgery to allow healing under decreased intra-cranial tension and to prevent any persistent cerebrospinal fistula (14). The under drainage and over drainage of cerebrospinal fluid can lead to a variety of complications.

7. COMPLICATIONS OF LUMBAR DRAINS

The complications of lumbar drains can be classified into major and minor complications. Various studies have found the complication rate to be 3% for major complications and between 5% - 5.3% for minor complications (14) (40) (46).

MAJOR COMPLICATIONS:

- TENSION PNEUMOCPHALUS:

  It is a rare and fatal complication of lumbar drain usage. Pneumocephalus occurs due to the accidental over drainage of cerebrospinal fluid which causes the patient to present with an acute drop in his neurological status.

  This occurs by either of two mechanisms. One is the ‘inverted bottle mechanism’ and the other is the ‘ball valve theory.’ The ‘inverted bottle mechanism’ can be explained as the replacement of the drained cerebrospinal fluid with air, owing to the pressure gradient that exists between the extracranial and intracranial compartments. The ‘ball

valve theory' is explained by a sudden increase in intracranial pressure, for example while sneezing or blowing the nose, which causes air entry into the intracranial compartment and subsequently causes air trapping (14). In the presence of a cerebrospinal fistula, the negative pressure gradient created between the atmospheric pressure and the intracranial pressure because of head end elevation and the continuous cerebrospinal fluid drainage, causes air entry into the intracranial space due to the siphon effect. The air then gets trapped in the intracranial space causing tension pneumocephalus (47). Erroneous placement of the cerebrospinal collection chamber can also cause over drainage and resultant pneumocephalus (17). Continued cerebrospinal fluid drainage in the presence of pneumocephalus can lead to brain herniation. Therefore, it is recommended to ensure that the rate of cerebrospinal fluid drainage does not exceed beyond 5-10ml/hr.

- TENTORIAL HERNIATION:

  The drainage of cerebrospinal fluid from below the level of the tentorium results in an increase in the pressure gradient between the lumbar subarachnoid space and the supra-tentorial region and leads to tentorial herniation (48). Pneumocephalus can further worsen tentorial herniation. Cases of tentorial herniation have been treated and recovered with the use of epidural blood patches (24) . Clamping of the drain for 8 hours has also shown to have an improvement in symptoms.

- SUBDURAL HEMATOMA AND SUBARACHNOID HEMORRHAGE:

  These patients present with an acute drop in their neurological status and may have seizures, contralateral weakness or confusion. Some cases of subdural hematoma may

require surgical evacuation. Increasing the height of the cerebrospinal fluid collection drain has also shown to improve the patient's symptoms and examination (24).

- MENINGITIS

  There are various risk factors responsible for the occurrence of meningitis due to the lumbar drain. Meningitis usually appears within 24 hours of lumbar drain placement. These risk factors may be the duration of leaving the lumbar drain in situ, direct introduction of a foreign body into the subarachnoid space, drain blockage or leak at the catheter or drain site. Oral or intravenous antibiotics are used for the treatment of bacterial meningitis. Some cases may require a ventriculoperitoneal shunt placement (49) (24) (14). Staphylococcus epidermidis and Enterococcus faecalis have been found to be the commonest causative agents for bacterial meningitis in the population with lumbar drains (40). In a rare occurrence, Enterococcus gallinarum has also been found to cause meningitis in patients with lumbar drains (50). However, lumbar drains are associated with a low risk of causing infectious meningitis and is safer than serial lumbar punctures and ventriculostomies. Antibiotics do not provide much prophylactic protection (51).

- LENGTH OF HOSPITAL STAY

  A failed lumbar cerebrospinal fluid drain can cause an intraoperative or postoperative cerebrospinal fluid leak or cerebrospinal fluid rhinorrhoea or cerebrospinal fluid fistula. These conditions may require surgical re-exploration and thus leading to an increase in the length of hospitalisation. The presence of a lumbar drain also implicates an increase in the length of hospitalisation, costs, laboratory studies and imaging expenses. The mean duration of hospitalisation has been found to be 5.4+/-

2.2 days for patients with a cerebrospinal fluid leak as compared to 3.5+/-1.9 days for patients with no cerebrospinal fluid leak (24).

- PERSONAL ERROR:

  This occurs due to miscommunication, multiple patient transfers and mishandling of the lumbar drain equipment. The instances of manhandling are disconnections, unwarranted opening of the drainage system and over-drainage of cerebrospinal fluid. Instances of miscommunication can occur with regards to incorrect opening and closing of the drain during controlled cerebrospinal fluid drainage (14) (24). All these personal errors also result in an increased risk for infection.

- DEEP VEIN THROMBOSIS:

  With the placement of a lumbar drain, the patient is ideally expected to be minimally mobile for 48-72 hours or even up to 5 days. This prolonged period of minimal or no mobility is a risk factor for deep vein thrombosis. However, the use of prophylactic heparin with an indwelling lumbar drain is controversial (45) (14). The use of alternative methods of deep vein thrombosis prophylaxis like the use of graded compression stockings and pneumatic boots have also been utilised in certain centres (40). In centres where the patients were allowed to ambulate, the drain was repositioned and fixed at the level of the tragus while the patient was seated and it was clamped when the patient was ambulating.

MINOR COMPLICATIONS:

- HEADACHE:

  Headache is an acknowledged result of procedures that reduce the spinal fluid volume and pressure, such as lumbar puncture, spinal anaesthesia and ventricular shunts. The incidence of headache after lumbar drain placement, has been found to be 63% by one authors and 58% by another author (17) (52).

  Due to the constant leak of cerebrospinal fluid from the subarachnoid space into the surrounding soft tissues of the back, there are symptoms of intrathecal hypotension. The intrathecal hypotension causes traction on the cranial nerves and meninges resulting in a headache. Another mechanism of headache is thought to be due to tension on the sensory receptors of the dura mater (53).

  The headache usually starts from 3 to 48 hours after lumbar drain placement and spontaneously resolves within 1 week or more. The symptoms have been found to regress on treatment with bed rest, intravenous fluids, analgesia and changes in the cerebrospinal fluid drainage rate (24). In the case of persistence of symptoms, an epidural blood patch has been proven to be an effective treatment modality (54).

- RETAINED CATHETER / CATHETER FRACTURE:

  The lumbar drain is usually removed on day 5 after its placement. During the removal of the catheter, it may fracture and get retained in the tissue. Removal of the catheter in its entirety can be confirmed by visualisation of the marked catheter tip. This complication usually occurs in cases where multiple attempts were made to thread the catheter or multiple punctures were made to place the lumbar drain. The treatment modality for a fractured catheter is careful observation with serial imaging of the lumbar spine and conservative management. Surgical removal of the fragment is

considered only if the patient is symptomatic, has comorbidities, depending on the size and location of the fragment, patient's desire to get the fragment removed and an increased risk of infection (55) (24).

- LOCAL INFECTION

  Improper aseptic techniques and inadequate sterilisation of the target area during the placement of the lumbar drain results in local infection. Certain risk factors like previous spine surgery, diabetes mellitus, intravenous drug abusers, alcohol consumers and the presence of multiple comorbidities, increases the chances of developing cellulitis. Cellulitis usually occurs at the catheter entry site. Symptomatic improvement is seen after treatment with oral or intravenous antibiotics.

- NERVE ROOT IRRITATION:

  This is typically characterised by a stabbing type of pain in the dermatomes of the sensory spinal nerve roots that come in contact with the Tuohy needle, during the procedure of lumbar drain placement. It rarely results in permanent nerve damage. Transient nerve root irritation can occur during the placement of the lumbar drain, with the drain in situ and after the drain is removed as well.

CONCLUSION:

There is a paucity of literature regarding the technical difficulties and complications faced by the Indian anaesthetists in placement of the lumbar drain with respect to the use of the epidural kits rather than the specifically designed lumbar drain kits, which are available in the international market.

The trend of placing lumbar subarachnoid drains for a variety of indications is only increasing and thus necessitates studies which focus on the practice of placement of lumbar drains in the Indian scenario.

MATERIALS AND METHODOLOGY

MATERIALS AND METHODOLOGY

SETTING: This is a hospital based study being performed in the neurosurgical wards, ICU and operating rooms of Christian Medical College, Vellore.

INCLUSION CRITERIA:

1. All Neurosurgery unit 1 patients scheduled for elective trans-nasal trans-sphenoidal resection of pituitary tumour requiring lumbar drain

2. Age from 18 years to 70 years

3. ASA I, II and III patients

EXCLUSION CRITERIA:

1. Patients unwilling to participate in the study

2. Age <18 years or >70 years

3. ASA IV and V patients

4. Patients with history of bleeding diathesis

5. Patients with infection at the site of drain insertion

6. Patients having systemic sepsis

7. Patients who have undergone previous spine operations

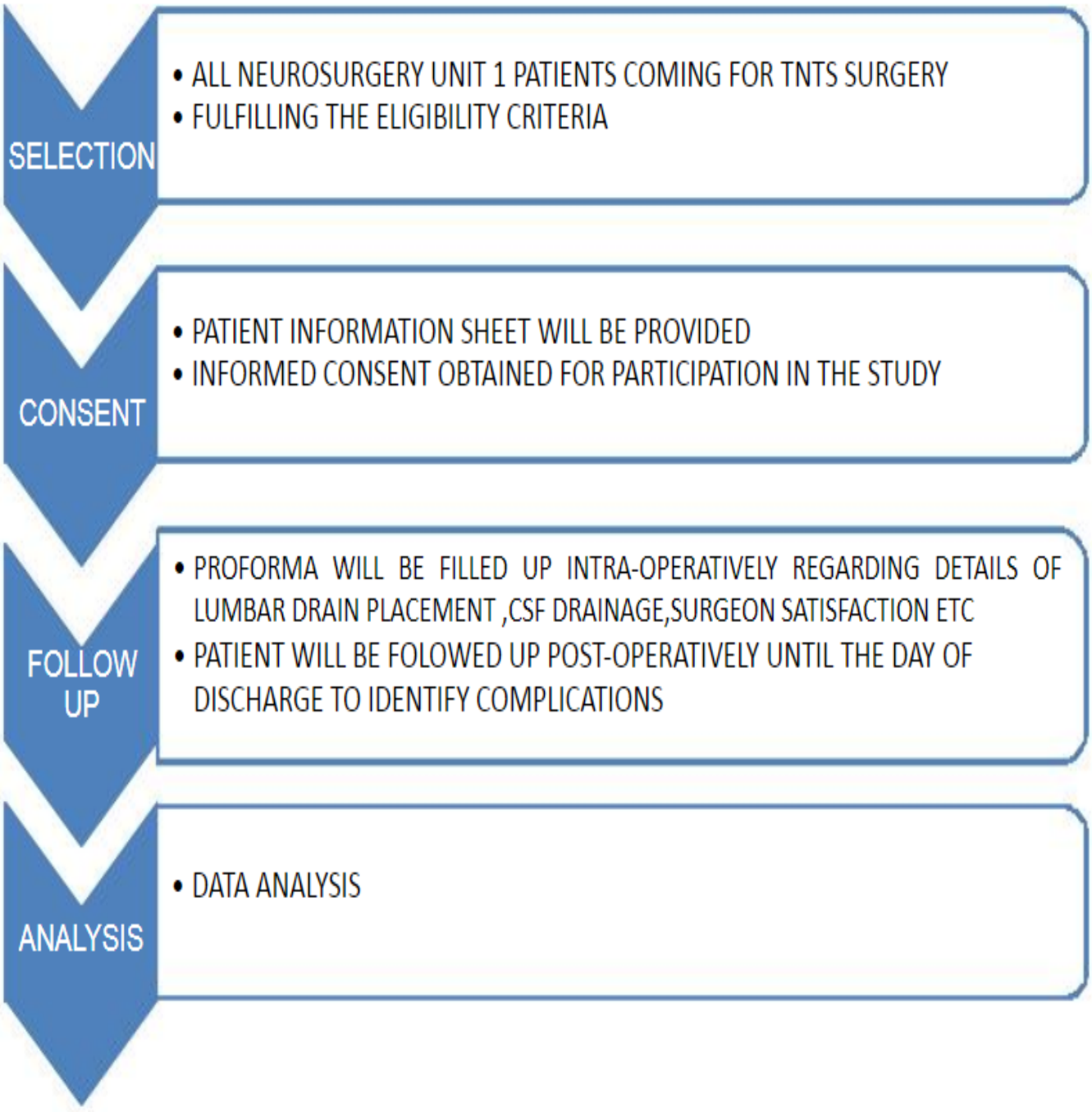
8. Pre-existing neurological deficits/ demyelinating lesions

Methods:

All Neurosurgery unit 1 patients, undergoing trans-nasal trans-sphenoidal resection of pituitary tumours, requiring pre-operative lumbar drain placement as planned by the neurosurgeon and who meet the inclusion criteria, will be recruited. The department of Neurosurgery unit 2, does not routinely place lumbar drains as per their protocol for trans-nasal trans-sphenoidal surgery. A detailed patient information sheet will be provided to the subjects and the primary investigator will explain the technique and need for placement of the lumbar drain. Informed consent will then be obtained from the subject. The technique of lumbar drain placement (midline vs paramedian approach) will be decided upon by the concerned anaesthesiologist at the time of surgery. The other intra-operative details will also be filled by the concerned anaesthesiologist in the proforma sheet. The patient will be followed up post-operatively by the primary investigator, up to one day after the completion of the surgery. The incidence of complications of lumbar drain placement, difficulty in placement, difficulty in drainage of CSF and the manoeuvres to improve the lumbar

CSF drainage will be assessed. The volume of CSF drained, presence or absence of CSF leak and the operative conditions, as assessed by the surgeon, will also be noted. The data will be analysed to arrive at the results.

Detailed algorithm of the study:



Bias:

The recording of the intra-operative details will be done by the concerned anaesthesiologist immediately after the procedure, thereby minimizing the risk of recall bias. The proforma shall be completed along with the discharge of the subject, so as to minimize bias and maintain the accuracy of information recorded.

Sample size:

To detect an incidence of 8.3% with a precision of 4%, we need a sample of 183 with 95% confidence interval. The following formula was used:

$$n = 4pq/d2$$

n = Sample size

p = Incidence of complications

q = 1- p

d = Precision of the estimate

The complication rates were taken from:

1. Hagel S, Bruns T, Pletz MW, Engel C, Kalff R, Ewald C. External Ventricular Drain Infections: Risk Factors and Outcome. Interdisciplinary Perspectives on Infectious Diseases. 2014; 2014: 1–6.

2. Stokken J, Recinos PF, Woodard T, Sindwani R. The utility of lumbar drains in modern endoscopic skull base surgery: Current Opinion in Otolaryngology & Head and Neck Surgery. 2015 Jan; 1.

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

Continuous data will be summarized using mean (SD)/ median (IQR) and categorical data will be expressed as numbers and percentages.

The incidence of the complication rate will be given with 95% confidence interval. The association between categorical variable in the profile and infection rate will be analysed using chi-square test. The relation between complication rate and continuous variables (like CSF amount, age, body mass index etc.) will be analysed using independent t-test.

The risk estimates will be presented as odds ratio (95% confidence interval). A multivariate logistic regression will be done to determine the risk factors for complication.

RESULTS

RESULTS

A total of 50 patients who underwent lumbar subarachnoid drain placement for trans-nasal trans-sphenoidal surgery for pituitary tumours, were recruited for this study. The difficulty in lumbar drain placement and complications arising from the lumbar subarachnoid drain were studied and analysed. Due to time constraints, the estimated sample size of 183 could not be achieved. However, an interim analysis was done with a sample size of 50.

Demographic Data:

- **Baseline characteristics:**

VARIABLE	MINIMUM	MAXIMUM	MEAN	S.D
Age (years)	18	76	42.18	14.26
Weight (kg)	43	110	83.14	95.86
BMI (kg/m^2)	16.9	33.9	26.48	4.37

Table 1: Baseline characteristics

S.D = standard deviation

- **Gender and ASA grading:**

VARIABLE	NUMBER	PERCENTAGE
SEX		
Male	28	56%
Female	22	44%
ASA Grade		
I	0	0
II	50	100%
III	0	0

Table 2 – Gender and ASA grading

Of the 50 patients included in the study, 22 patients (44%) were female and 28patients (56%) were male

All the 50 patients included in the study were ASA grade II.

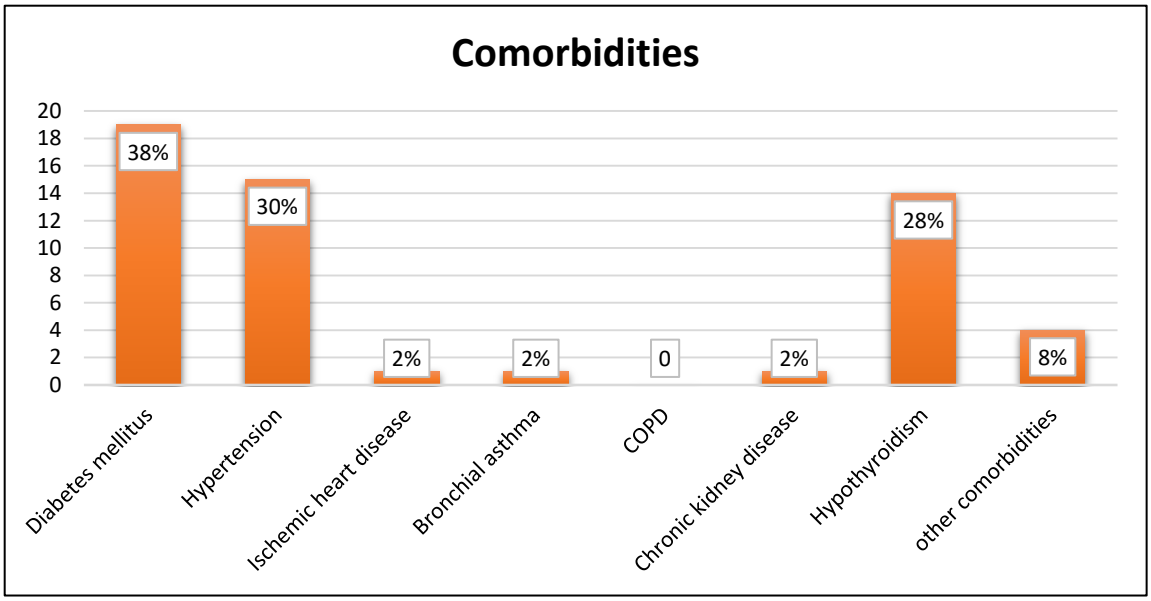
- **Comorbidities**

All the 50 patients recruited were classified as ASA class II owing to the presence of mild disease without substantive functional limitations. The comorbidities were further noted and analysed.

Of the 50 patients included in the study, 19 patients (38%) had diabetes mellitus type 2, 15 patients (30%) had hypertension, 1 patient (2%) had ischemic heart disease, 1 patient (2%) had bronchial asthma, 1 patient (2%) had chronic kidney disease and 14 patients (28%) had hypothyroidism.

There were no patients with chronic obstructive pulmonary disease in the study group.

There were 4 patients (8%) with other comorbidities like Klippel Feil syndrome,



obesity, psychiatric disorder and seizure disorder.

Figure 11 – Comorbidities

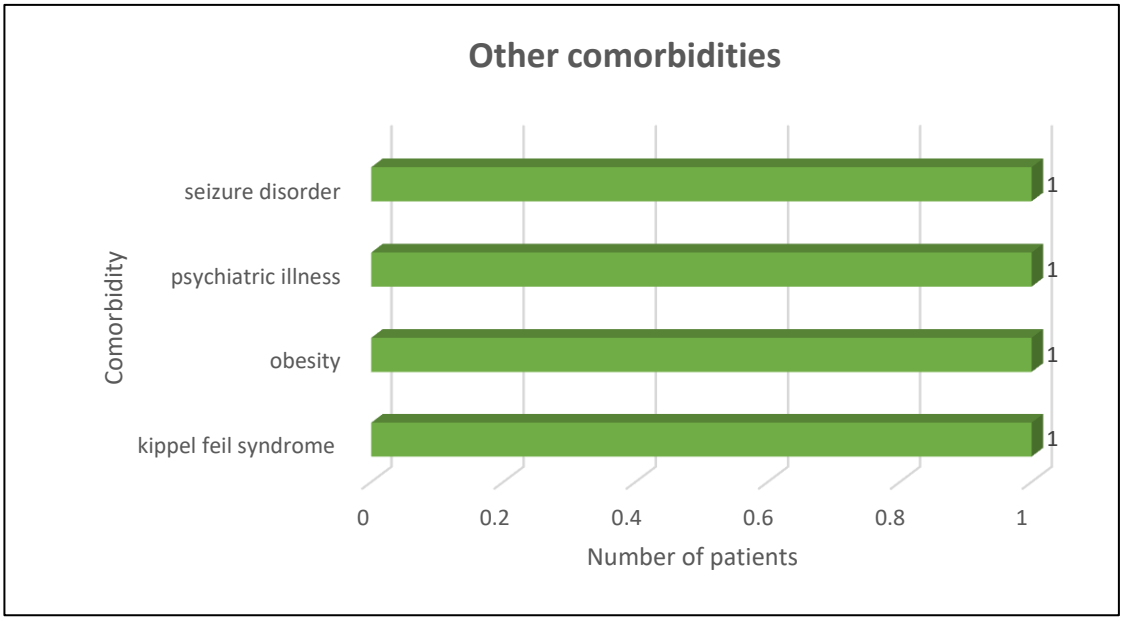


Figure 12 – Other comorbidities

Of the 50 patients included in the study, 4 patients (8%) were grouped together for having other comorbidities. 1 patient (2%) had Klippel Feil syndrome, 1 patient (2%) had obesity, 1 patient (2%) had a psychiatric disorder and 1 patient (2%) had seizure disorder.

Preoperative risk factors for complications:

Risk Factor	Number	Percentage
Tumour size		
Macro-adenoma	39	78%
Micro-adenoma	7	14%
Unclassified	4	8%
Suprasellar extension		
Present	37	74%
Absent	13	26%
Prev. h/o LSAD/EVD/Pituitary Surgery		
Present	5	10%
Absent	45	90%
Prev. h/o meningitis		
Present	1	2%
Absent	49	98%
Prev. positive Csf culture		
Present	2	4%
Absent	48	98%
Prior positive blood culture		
Present	1	2%
Absent	49	98%
Prior positive urine culture		
Present	0	0
Absent	50	100%
Prior wound culture		
Present	1	2%
Absent	49	98%

Table 3 - Summary of preoperative risk factors for complications

- **Macro-adenomas:**

  Pituitary adenomas are called ‘macro-adenomas’ if the tumour measures more than 10millimeters in size. They are called ‘micro-adenomas’ if it measure less than 10millimeters in size.

  Of the 50 patients included in the study, 38 patients (76%) were found to have a pituitary macro-adenoma and 12 patients (24%) were found to have micro-adenomas.

- **Suprasellar extension of pituitary tumour:**

  Of the 50 patients included in the study, 37 patients (74%) had pituitary tumours which extended into the suprasellar region of the brain and 13 patients (26%) had pituitary tumours which did not extend into the suprasellar region.

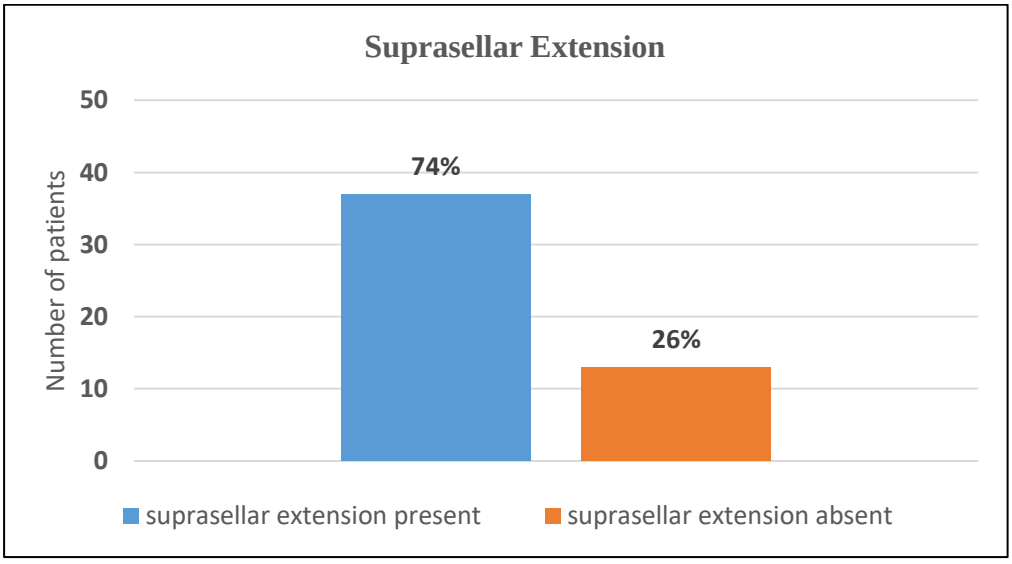


Figure 13 – Suprasellar extension

- **Previous history of lumbar subarachnoid drain/ external venrtricular drain/ pituitary surgery:**

  Of the 50 patients included in the study, 5 patients (10%) gave a prior history of having undergone a lumbar subarachnoid drain placement or external ventricular drainage or a pituitary surgery. 45 patients (90%) gave no history of undergoing any of the above mentioned procedures.

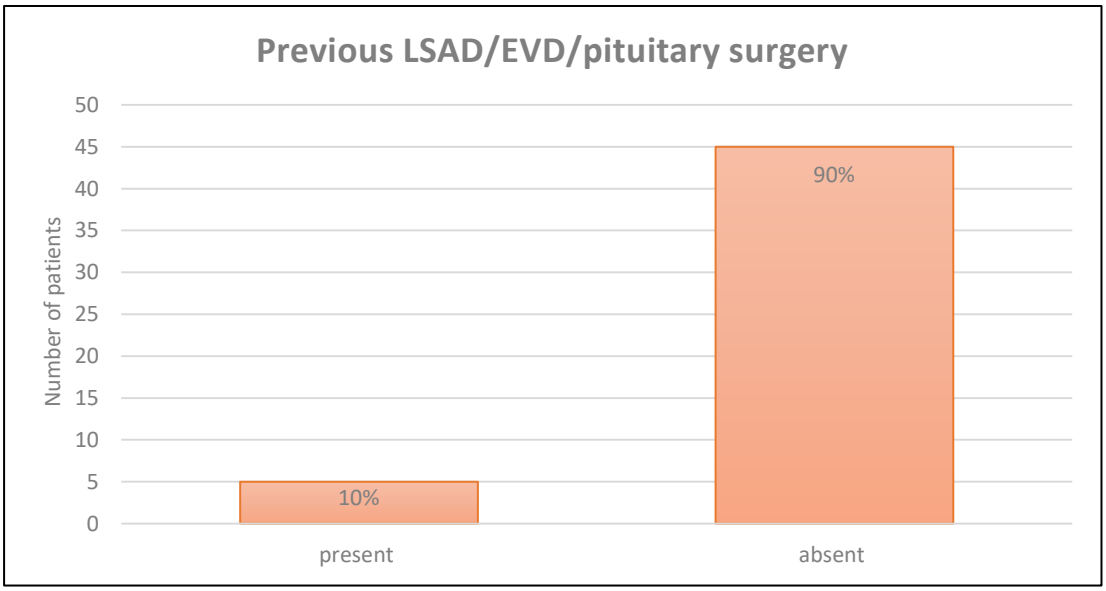


Figure 14 – Previous history of LSAD (lumbar subarachnoid drain), EVD (external ventricular drainage) or pituitary surgery.

- **Coagulation parameters:**

  Coagulation parameter investigations, namely PT (prothrombin time), INR (international normalized ratio) and APTT (activated partial thromboplastin time), were done only for 5 patients (10%) out of the 50 patients who were included in the

study. The coagulation parameters were not done for 45 patients (90%) of the total 50 patients, as it is not a routine preoperative investigation required prior to surgery.

All the 5 patients (10%) who had undergone the coagulation parameter investigations, had an underlying risk factor for coagulation abnormalities, but had normal results.

- **Previous history of meningitis:**

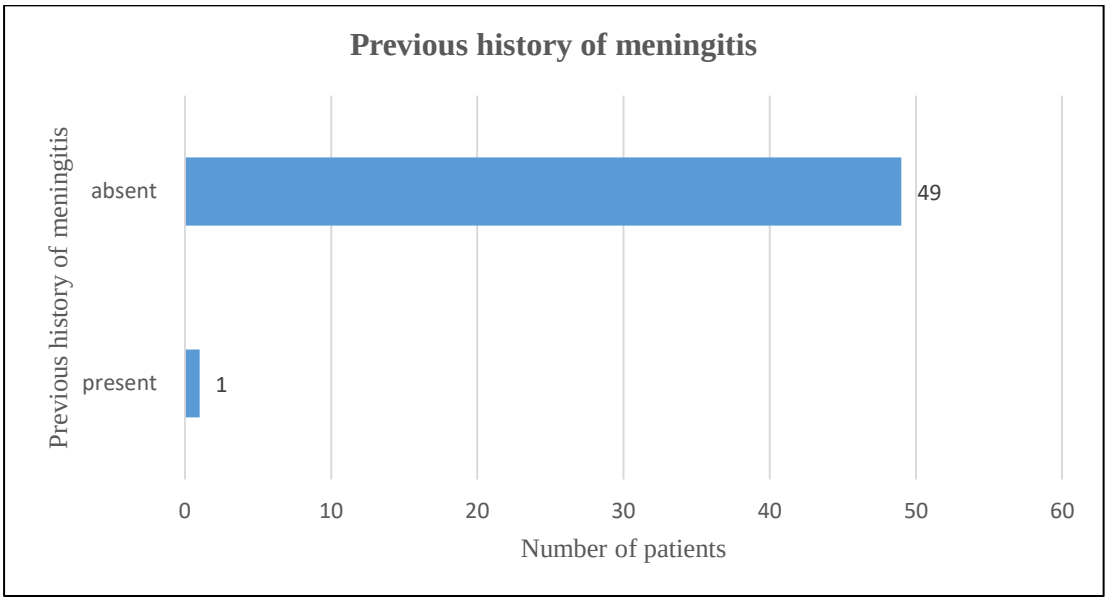


Figure 15 – Previous history of meningitis

Only 1 patient (2%) of the 50 patients in the study, previously had an episode of meningitis. 49 patients (98%) of the 50 patients had never had meningitis previously.

PRIMARY OUTCOMES

Intraoperative Details:

	Detail	Number	Percentage
Timing	Intubated	45	90%
	Non-intubated	5	10%
Approach	Midline	45	90%
	Paramedian	5	10%
Difficulties encountered in LSAD placement	Yes	32	64%
	No	18	36%

Table 4 – Summary of intraoperative details

- **LSAD (Lumbar subarachnoid drain) placement – intubated or non-intubated:**

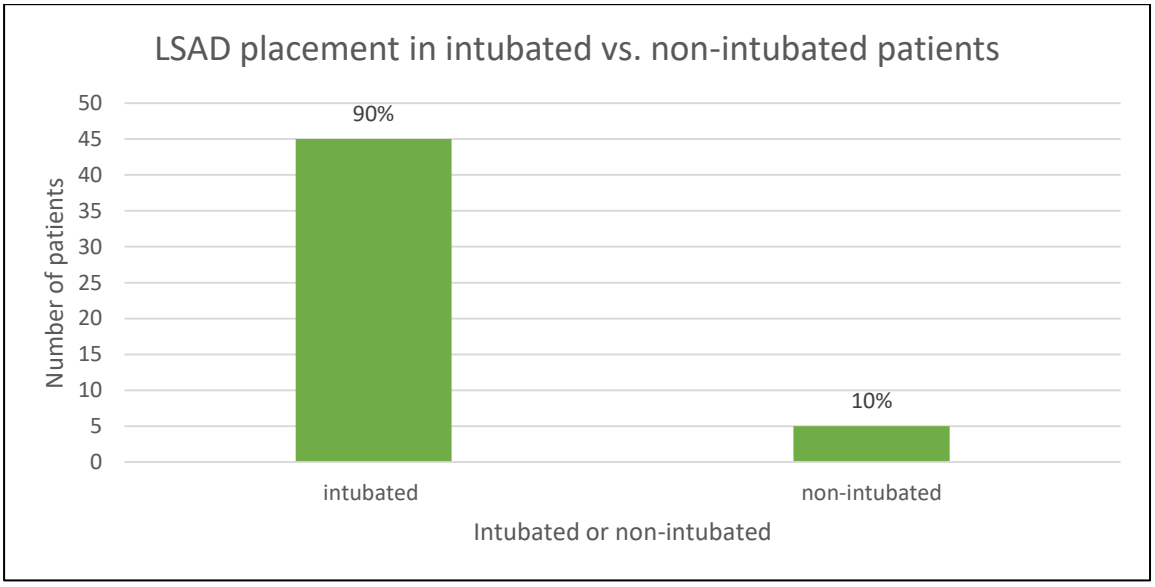


Figure 16 – LSAD placement in intubated vs. non-intubated patients

The lumbar subarachnoid drain was placed after endotracheal intubation in 45 patients (90%) and before endotracheal intubation in 5 (10%) patients.

- **Timing of lumbar subarachnoid drain placement – midline or paramedian:**

  The lumbar subarachnoid drain was placed using the midline approach in 45 patients (90%) out of the 50 patients included in the study. It was placed using the paramedian approach in 5 patients (10%).

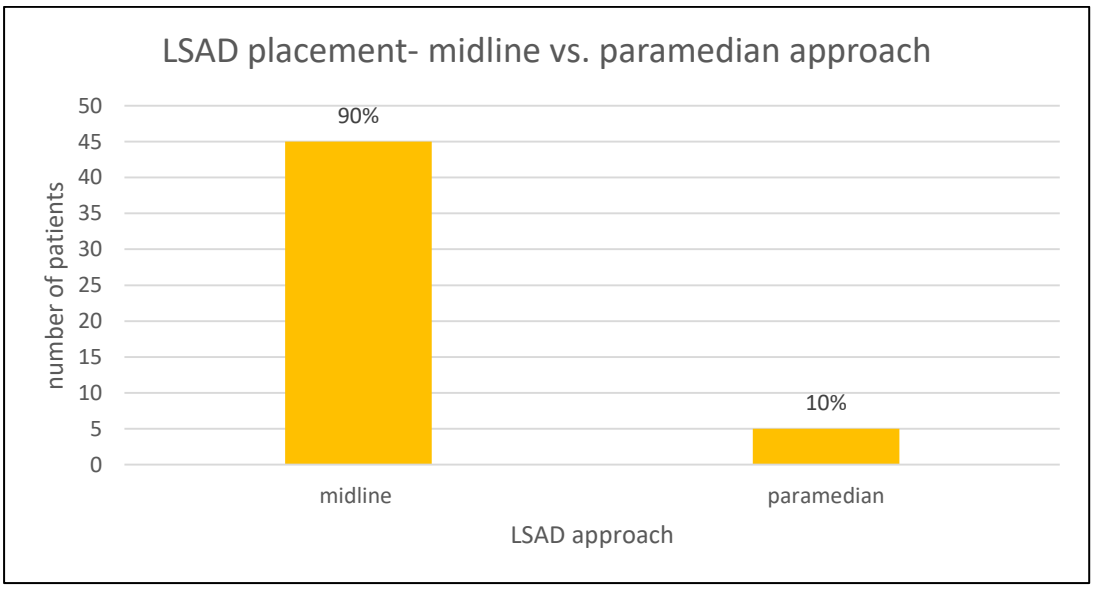
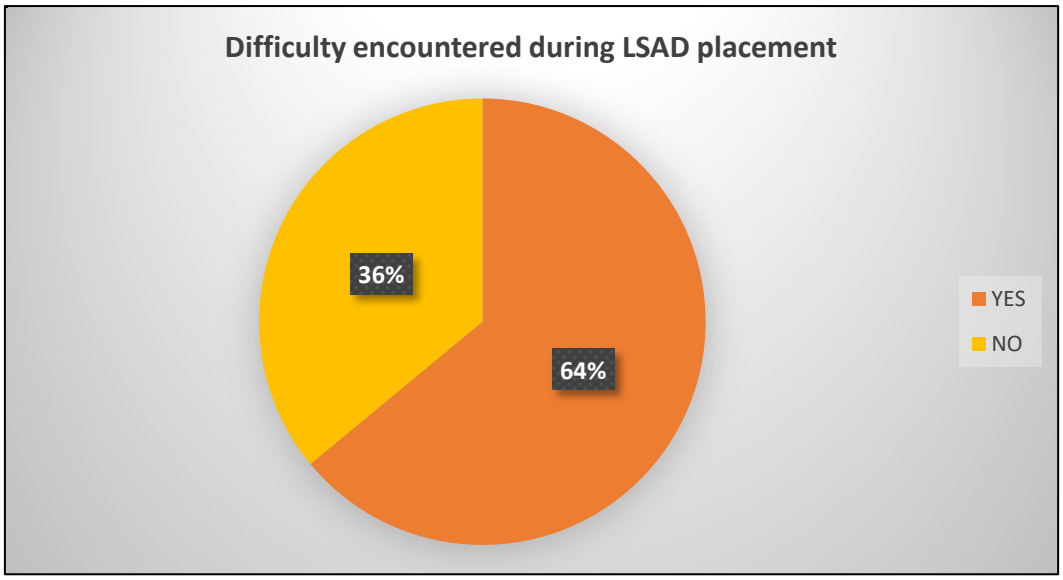


Figure 17 – LSAD placement – midline vs. paramedian approach



- **LSAD placement – Difficulties in placement:**

Figure 18 – Difficulties encountered during placement of LSAD

Of the 50 patients included in the study, there were difficulties encountered in placement of the lumbar subarachnoid drain in 32 patients (64%). No difficulties were faced in placement of the lumbar subarachnoid drain in 18 patients (36%). The difficulties encountered included difficulty in tapping the lumbar space requiring multiple number of attempts or attempts at multiple levels, difficulty in citing the catheter after identifying the space and difficulty in drainage of cerebrospinal fluid after citing the catheter. All the afore-mentioned difficulties were observed and analysed.

	Detail	Number	Percentage
Difficulty in tapping lumbar space	Yes	25	78.13%
	No	7	21.88%
Difficulty in citing catheter	Yes	15	46.88%
	No	16	50%
	Unable to thread	1	3.13%
Difficulty in CSF drainage	Yes	10	31.25%
	No	22	68.75%

Table 5 – Summary of difficulties in lumbar subarachnoid drain placement

- **Difficulty in tapping lumbar space:**

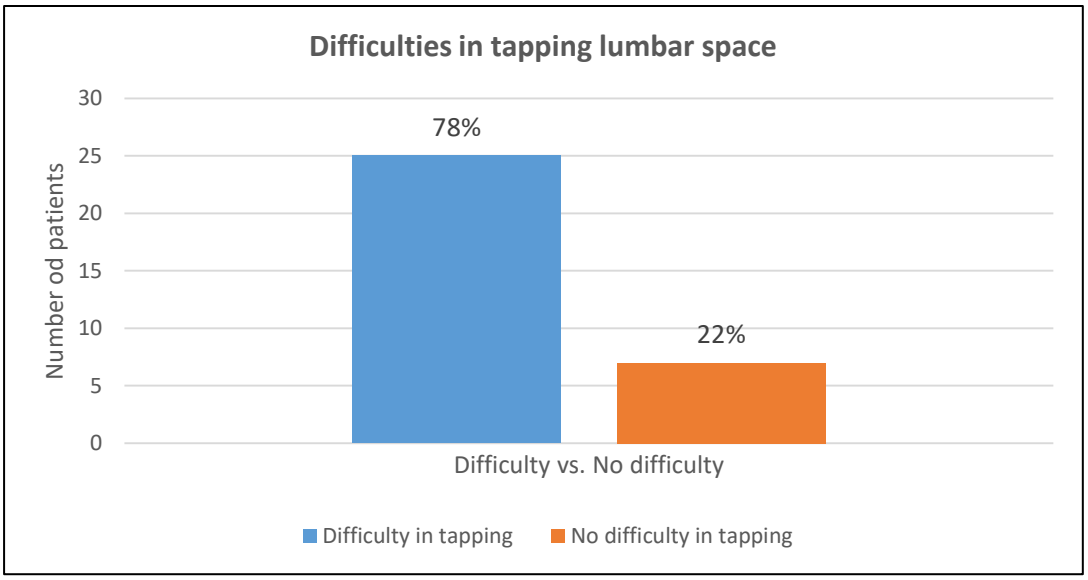


Figure 19 – Difficulties in tapping the lumbar space

There was difficulty in tapping the lumbar space in 25 patients (78%) out of the 32 patients in the study, who had difficulty in lumbar subarachnoid drain placement. Whereas there was no difficulty in tapping the lumbar space in 7 patients (22%). Hence, the difficulty in LSAD placements in these 7 patients may have stemmed from either difficulty in citing the catheter or difficulty in cerebrospinal fluid drainage.

	Detail	Number	Percentage
Difficulty in tapping lumbar space	No. of attempts		
	1	3	10.34%
	2	11	37.93%
	3	12	41.38%
	4	3	10.34%
	No. of levels		
	1	16	55.17%
	2	11	37.93%
	3	2	6.90%

Table 6 – Summary of difficulties in tapping lumbar space

NUMBER OF ATTEMPTS:

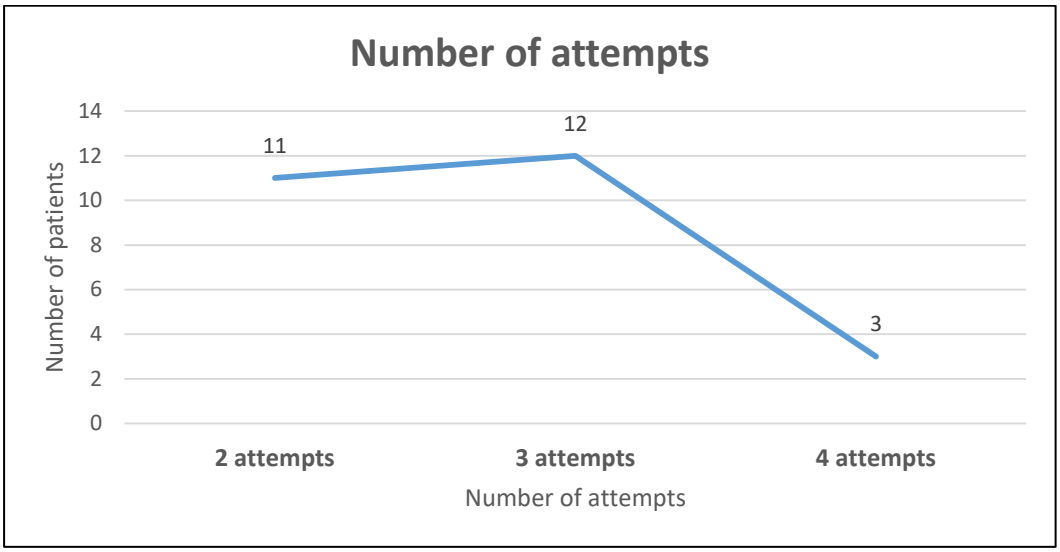


Figure 20 – Number of attempts taken for placement of LSAD

More than one attempt was documented as a difficulty in lumbar subarachnoid drain placement. 2 attempts were required for successful placement of the LSAD (lumbar subarachnoid drain) in 11 patients. 3 attempts were required in 12 patients and 4 attempts were required in 3 patients for successful LSAD placement.

NUMBER OF LUMBAR INTERVERTEBRAL SPACES/LEVELS ATTEMPTED:

Attempts at more than one lumbar intervertebral space/level was considered to be a difficult lumbar subarachnoid drain placement. 2 levels were attempted in 11 patients before successfully placing the LSAD (lumbar subarachnoid drain). 3 levels were attempted in 2 patients before LSAD placement.

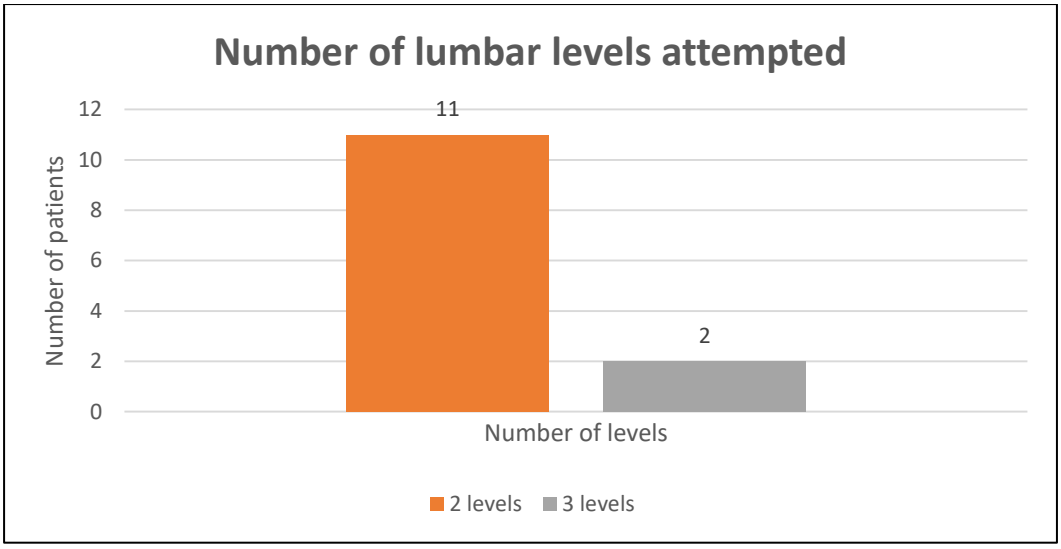


Figure 21 – Number of lumbar levels attempted

- **Difficulties in citing the catheter:**

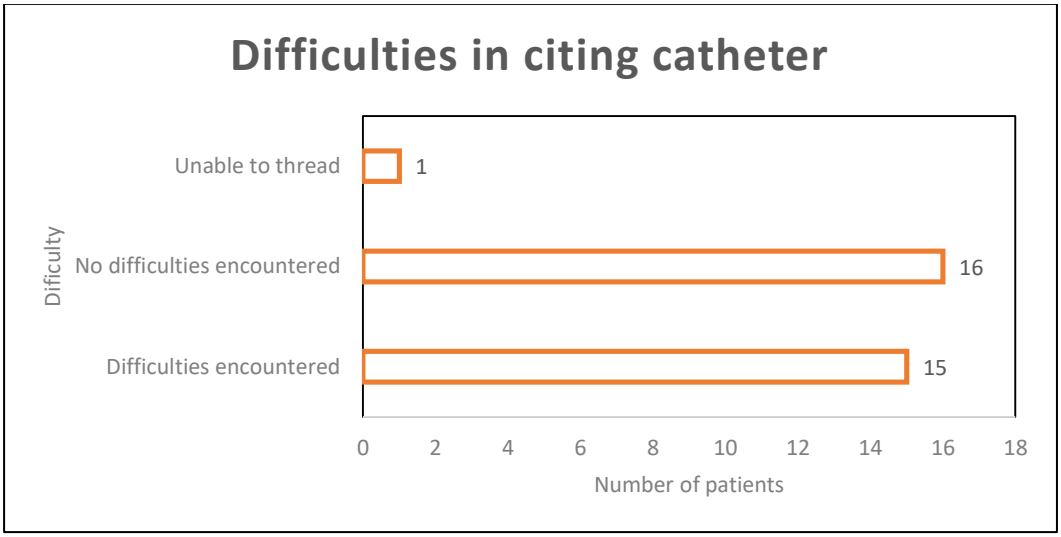


Figure 22 – Difficulties in citing the catheter

Difficulties in citing the catheter which are more than 1 attempt required to place the catheter or the use of manipulations to place the catheter were considered as difficulty in lumbar subarachnoid drain placement. There was difficulty in citing the catheter in 15 patients. It was not possible to thread the catheter at all in 1 patient, which

ultimately required the identification of an entirely different lumbar space. There were no difficulties in citing the catheter for 16 patients. Hence, the difficulty in lumbar subarachnoid drain placement for these 16 patients must have stemmed from either difficulty in tapping the lumbar space or from difficulty in cerebrospinal fluid drainage.

- **Difficulty in cerebrospinal fluid drainage requiring manipulations:**

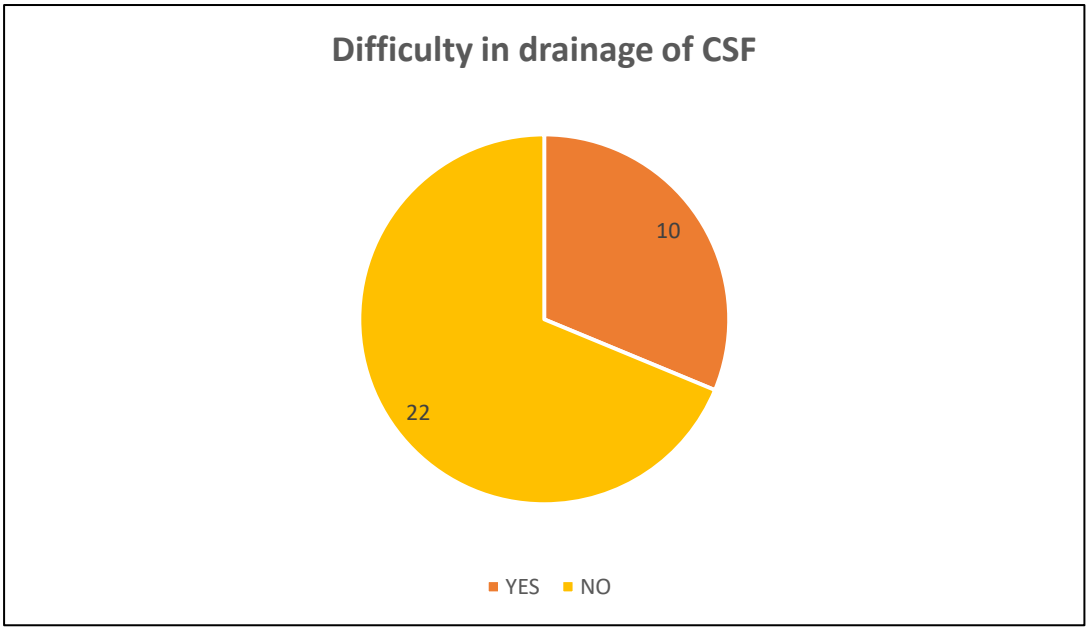


Figure 23 – Difficulty in drainage of cerebrospinal fluid after catheter placement

CSF = cerebrospinal fluid

Of the 32 patients in whom there was difficulty in lumbar subarachnoid drain placement, 10 patients had difficulty in cerebrospinal fluid drainage after placement of the lumbar subarachnoid drain. 22 patients had no difficulty in cerebrospinal fluid drainage and hence, the difficulty in lumbar drain placement in these patients may be accredited to difficulty in lumbar space tapping or difficulty in citing the catheter.

USE OF MANIPULATION TO IMPROVE THE CEREBROSPINAL FLOW RATE:

Manipulation was done to improve the cerebrospinal flow rate in all 10 of the patients in whom there was difficulty in drainage of cerebrospinal fluid. 22 patients who had difficult in lumbar drain placement but no difficulty in cerebrospinal fluid drainage after the lumbar drain placement, did not require any manipulations.

MANIPULATIONS USED TO IMPROVE THE CEREBROSPINAL FLUID FLOW RATE:

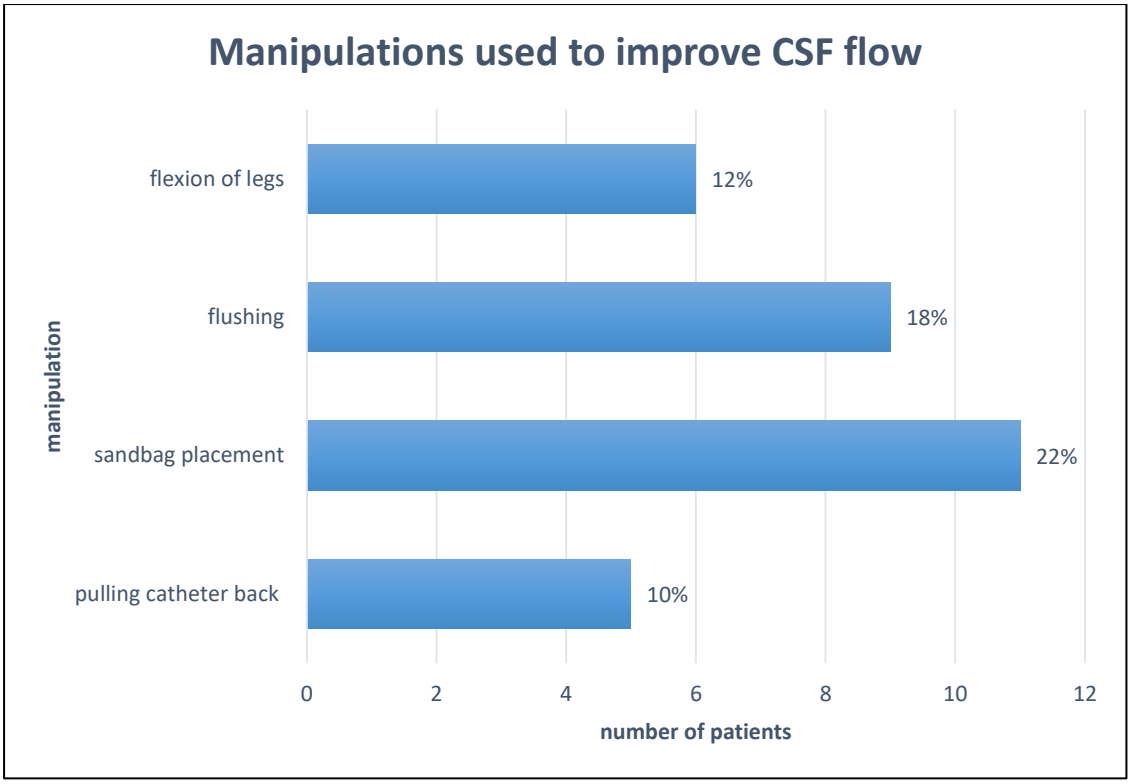


Figure 24 – Manipulations done to improve the cerebrospinal fluid flow

CSF = cerebrospinal fluid

Several manipulations can be performed in an attempt to improve the cerebrospinal flow rate after positioning the patient for surgery. Some of these manipulations are

pulling back the catheter, placing a sandbag under the patient's back, flushing of the catheter and flexion of the legs.

31 manipulations were done on 10 patients. Following a decrease or no cerebrospinal fluid flow, pulling back the catheter was done in 5 patients (10%), sandbag placement was done in 11 patients (22%), flushing was done in 9 patients (18%) and the legs were flexed in 6 patients (12%). More than one manipulations have also been attempted on the same patient.

- **Changes in cerebrospinal fluid flow after positioning:**

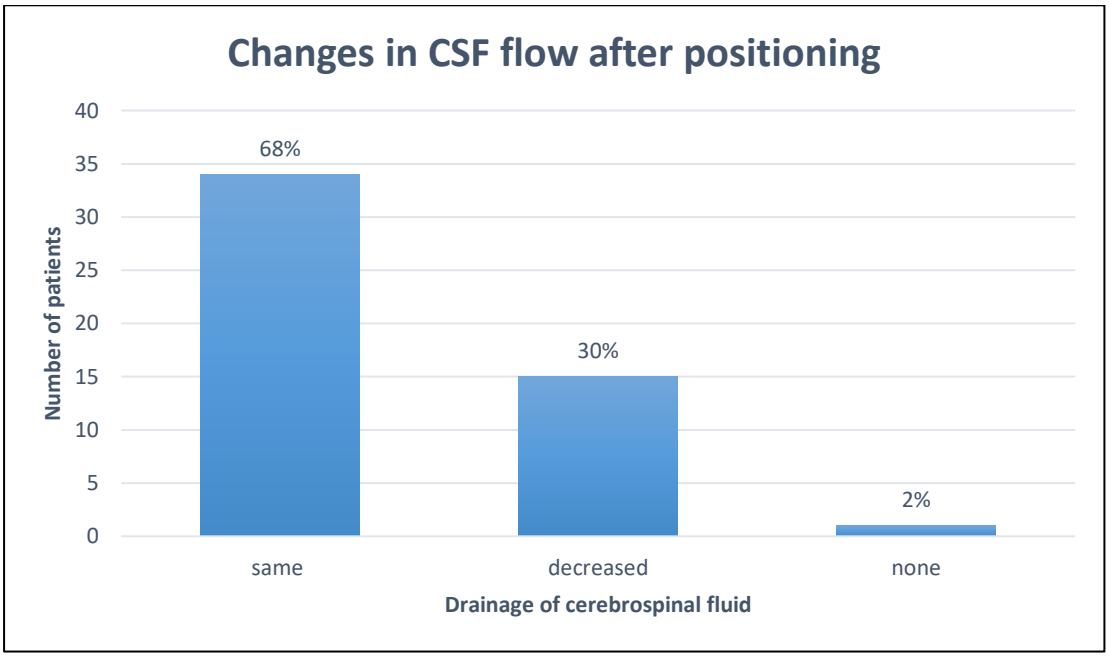


Figure 25 – Changes in cerebrospinal fluid flow rate after positioning

CSF = cerebrospinal fluid

Of the 50 patients included in the study, 34 patients (68%) were observed to have the same rate of cerebrospinal fluid flow after positioning the patient as after placement

of the lumbar subarachnoid drain. 15 patients (30%) had a decrease in cerebrospinal flow rate and 1 patient (2%) was observed to have no cerebrospinal fluid flow at all.

- **Type of lumbar drain:**

  Of the 50 patients included in the study, Portex epidural kit was used for lumbar drain placement in 46 patients (92%) and Braun epidural kit was used for 4 patients (8%).

- **Fixation of lumbar drain:**

  The lumbar drain was fixed in place with Tegaderm with pad in 40 patients (80%) of the 50 patients included in the study. In 4 patients (8%), plain Tegaderm along with a gauze was used to fix the drain. In the remaining 6 patients (12%), Lock it plus was used to fix the lumbar drain in place.

- **Surgeons' satisfaction with intraoperative conditions:**

  Of the 50 patients included in the study, the operating surgeon found the intraoperative conditions to be 'excellent' in 13 patients (26%), 'satisfactory' in 29 patients (58%) and 'poor' in 8 patients (16%) .

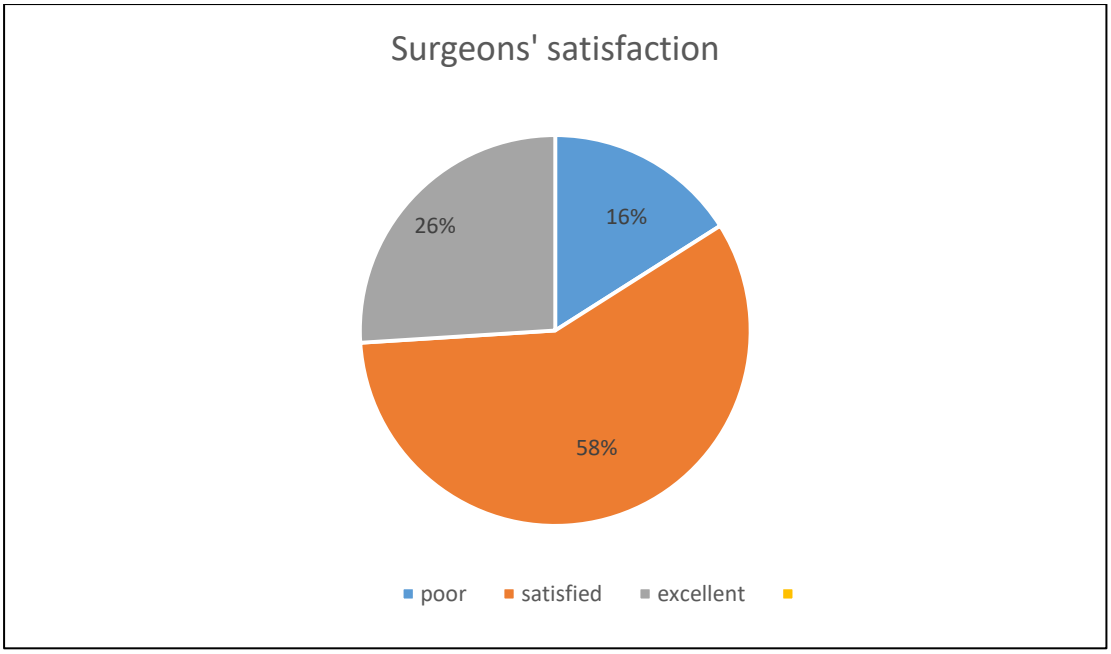


Figure 26 – Surgeons' satisfaction with the intraoperative conditions

- EFFECT OF THE TOTAL VOLUME OF CEREBROSPINAL FLUID DRAINED ON THE SURGEONS' SATISFACTION

Variable	Mean	S.D	P value
surgeon-poor			
total csf(ml)	18.25	16.71	
surgeon-satisfied			
total csf(ml)	85.31	46.85	**0.0003**
surgeon-excellent			
total csf(ml)	91.92	46.93	

Table 7 - Total volume of cerebrospinal fluid drained vs surgeon satisfaction

***P value = 0.0003**

The effect of the total volume of cerebrospinal fluid drained is a very significant factor for surgeon satisfaction. The surgeon satisfaction tends to be more when a greater volume of cerebrospinal fluid is drained. The *P value for this finding is 0.0003 (P value <0.05).

- EFFECT OF THE CEREBROSPINAL FLUID LEAK ON THE SURGEONS' SATISFACTION

T

CSF leak	Surgeons' Satisfaction			P value
	Poor	Satisfied	Excellent	
Yes	6 (75%)	4 (13.79%)	1 (7.69%)	0
No	2 (25%)	25 (86.21%)	12 (92.31%)	

Effect of cerebrospinal fluid leak on the surgeons' satisfaction

***P value = 0.000**

The surgeons have been found the intra-operative conditions to be satisfactory in 25 patients (86.21%) and excellent in 12 patients (92.31%) in the setting of an absence of cerebrospinal fluid leak. This finding has been found to be very significant, *P value = 0 (P value<0.05)

- **Experience of the anaesthesia provider:**

Variable	n	Mean	S.D	Minimum	Maximum
experience(years)	50	5.5	4.69	1	20

Table 9 – Characteristics of the experience of the anaesthesia operator

Experience = experience of the anaesthesia provider (in years) and n = number of patients

It was observed that the mean age of the anaesthetist performing the lumbar drain procedure was 5.5 years, with the minimum experience of the operator being 1 year and the maximum experience of the anaesthesia operator being 20 years.

- **Total volume of cerebrospinal fluid drained:**

Variable	n	Mean	S.D	Minimum	Maximum
Total csf (ml)	**50**	**76.3**	**49.96**	**0**	**200**

Table 10 - Total volume of cerebrospinal fluid drained

CSF = cerebrospinal fluid, ml = millilitres and n = number of patients

The total volume of cerebrospinal fluid drained by the lumbar subarachnoid drain was observed to be a mean of 76.3 ml. The minimum volume to be drained was 0ml and the maximum volume to be drained was 200ml.

- **Presence of cerebrospinal fluid leak during surgery and fate of the lumbar subarachnoid drain after completion of the surgery:**

VARIABLE	NUMBER	PERCENTAGE
CSF LEAK		
Present	11	22%
Absent	39	78%
LSAD		
Left in situ	16	32%
Removed	34	68%

Table 11 – Cerebrospinal fluid leak detection intra-operatively and fate of the lumbar subarachnoid drain after completion of the surgery

CSF = cerebrospinal fluid

11 patients (22%) of the 50 patients included in the study were found to have an intra-operative cerebrospinal fluid leak whereas 39 patients (78%) did not have any intra-operative cerebrospinal fluid leak.

The lumbar subarachnoid drain was removed at the end of the surgery in 34 patients (68%) of the 50 patients included in the study. The lumbar drain was left in situ for 5

days in 16 patients (32%) of which, 4 of the patients had no cerebrospinal fluid leak but the lumbar drain was still left in situ as per the request of the surgeons.

- **Administration of antibiotics:**

  All 50 patients included in the study, received prophylactic antibiotics (Ceftriaxone) prior to the commencement of the surgery.

Postoperative complications

- **Insufficient cerebrospinal fluid drainage:**

  5 patients (10%) out of the 50 patients included in the study, were found to have insufficient cerebrospinal fluid drainage from the lumbar drain left in situ after the surgery. 45 patients (90%) had no problem of insufficient drainage. These 45 patients were inclusive of the patients who had their lumbar drains removed and those who had lumbar drains in situ which were draining adequate cerebrospinal fluid.

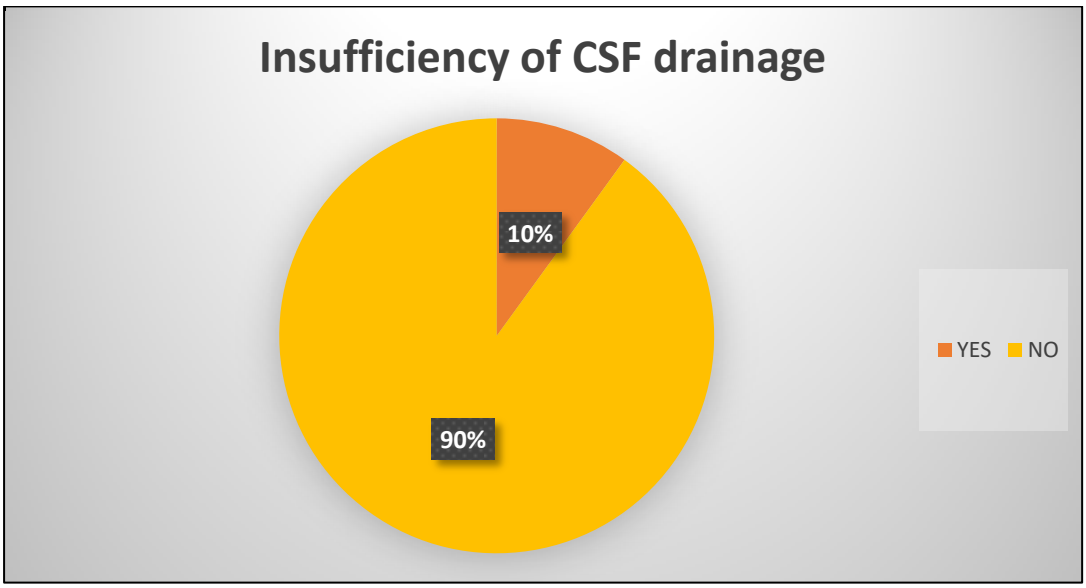


Figure 27 – Insufficiency of cerebrospinal fluid drainage

CSF = cerebrospinal fluid

- **Presence of cerebrospinal fluid leak from the lumbar drain:**

  None of the 50 patients included in the study had cerebrospinal fluid leaking from the lumbar drain.

- **Lumbar subarachnoid drain disconnection:**

  None of the 50 patients included in the study had a disconnection in the lumbar subarachnoid drain equipment.

- **Dressing changes for the lumbar subarachnoid drain:**

  The dressing for the lumbar subarachnoid drain had to be changed in 7 patients (14%) of the 50 patients included in the study. The dressing was not changed in 43 patients (86%).

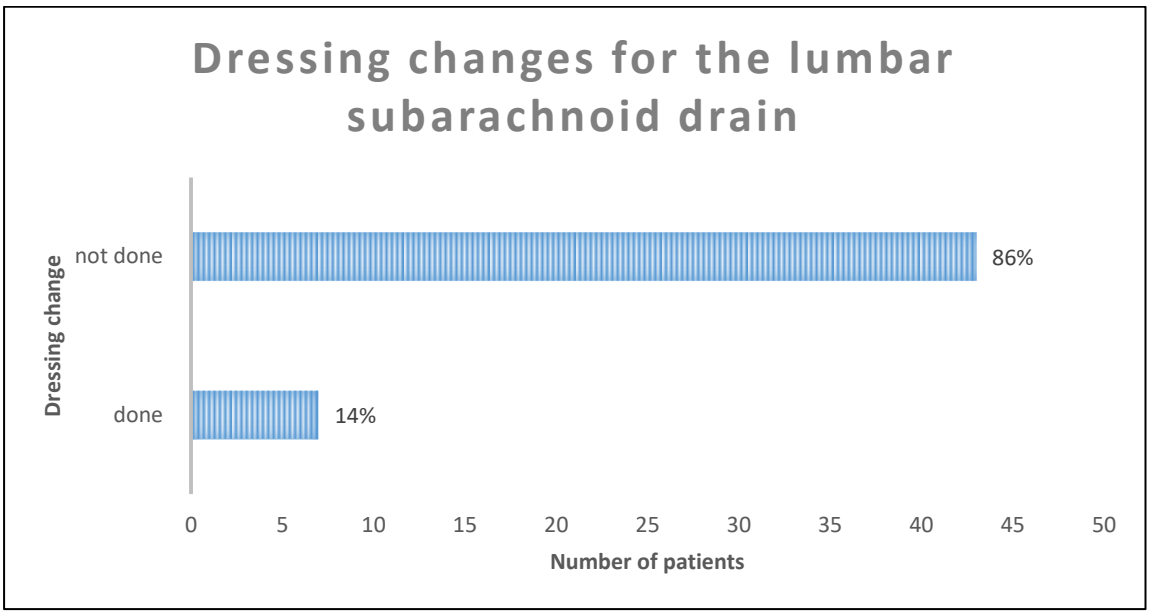


Figure 28 – Dressing changes for the lumbar subarachnoid drain

- **Lumbar subarachnoid drain system changes after initial placement:**

  Changes in the lumbar subarachnoid drain system had to be made in 7 patients (14%) after its initial placement. The lumbar drain system did not require any changes in its system in 43 patients (86%).

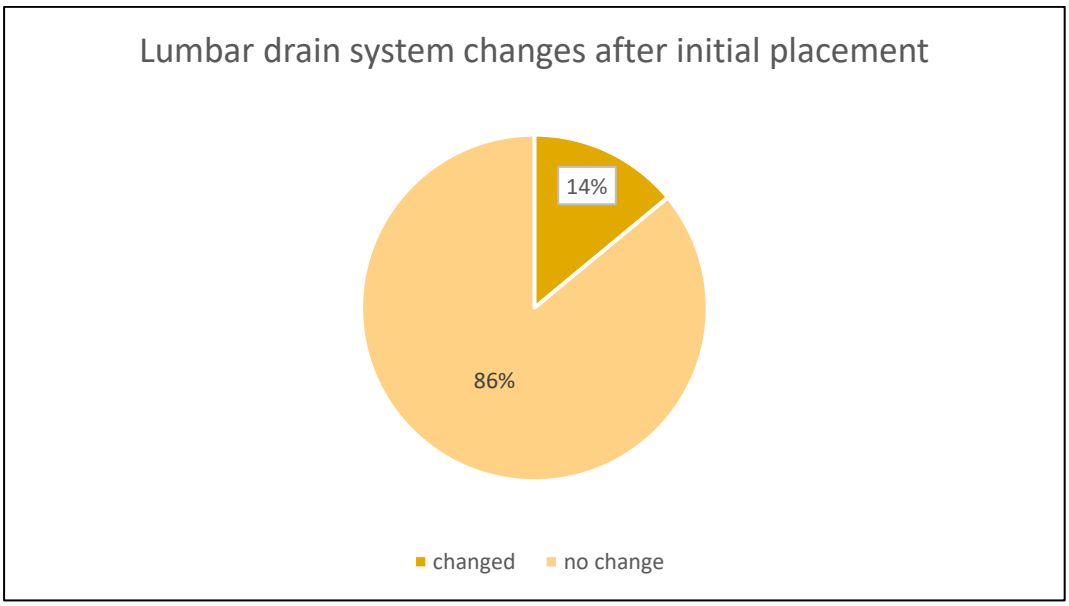


Figure 29 – Lumbar subarachnoid drain system changes after initial placement

- **Retained catheter:**

  There were no instances of retained lumbar drain catheter among the 50 patients included in the study.

- **Presence of nerve root irritation of neuralgia:**

  There were no instances of nerve root irritation among the 50 patients included in the study.

- **Presence of erythema/ purulence/ induration or hematoma:**

  There were no instances of erythema, purulence, induration of hematoma at the site of the lumbar subarachnoid drain placement among the 50 patients included in the study.

- **Meningitis:**

  There were no instances of meningitis among the 50 patients included in this study.

- **Backache:**

  13 patients (26%), out of the 50 patients in the study, complained of backache after the surgery. 37 patients (74%) did not have any complaints of backache after the surgery.

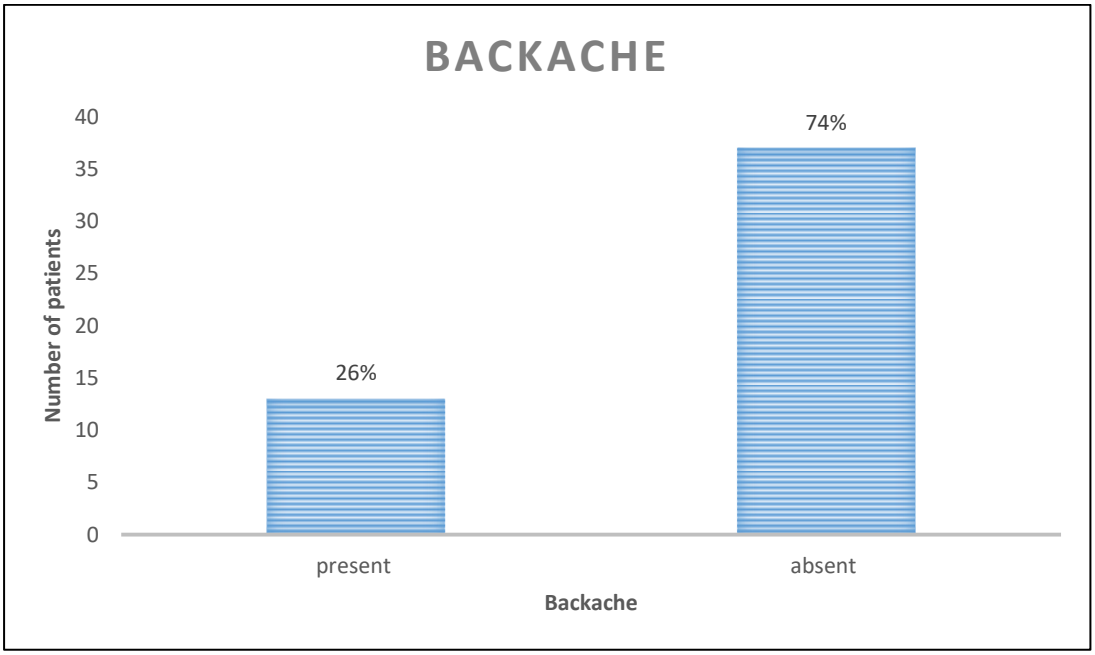


Figure 30 – Backache

- **Headache:**

  28 patients (56%), out of the 50 patients included in the study, complained of headache after the surgery. 22 patients had no complaints of headache after the surgery.

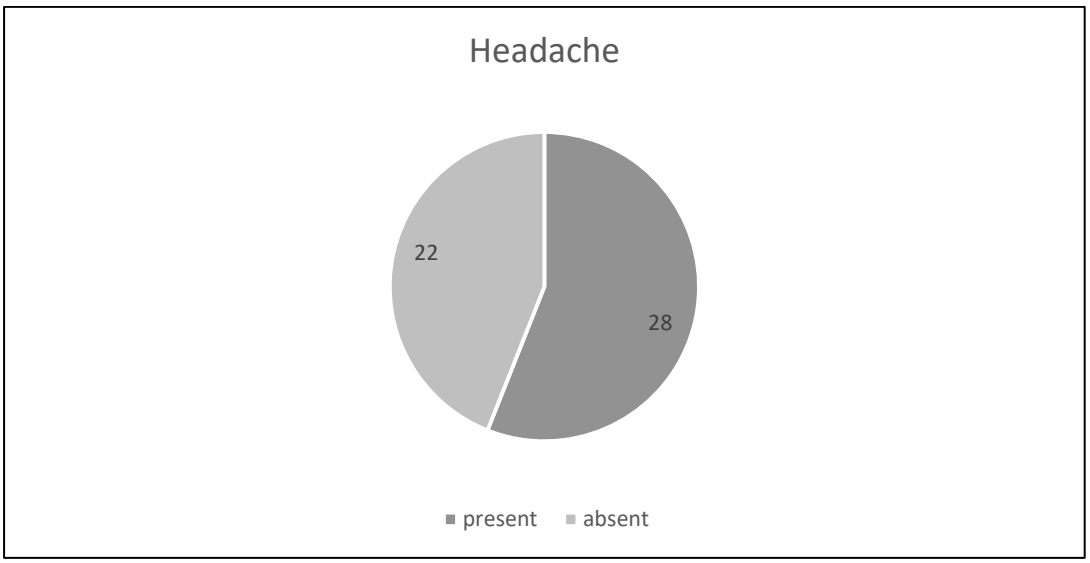


Figure 31 – Headache after surgery

SECONDARY OUTCOMES

- **Characteristics of the complications arising from the lumbar subarachnoid drain:**

VARIABLE	MEAN	95 % CONFIDENCE	INTERVAL
CSF Leak at the end of surgery	**22%**	**11.53**	**35.96**
Insufficient CSF drainage	**10%**	**3.3**	**21.8**
CSF leak from LSAD	**0**	**0**	**7.1**
LSAD system disconnection	**0**	**0**	**7.1**
Dressing changes for LSAD	**14%**	**5.8**	**26.7**
LSAD system change after initial placement	**14%**	**5.8**	**26.7**
Retained catheter	**0**	**0**	**7.1**
Presence of nerve root irritation	**0**	**0**	**7.1**
Presence of erythema/purulence/induration/hematoma	**0**	**0**	**7.1**
Post-op meningitis	**0**	**0**	**7.1**
Backache	**26%**	**14.6**	**40.3**
Headache	**56%**	**41.2**	**70.0**

Table 12 – Characteristics of the complications arising from the lumbar subarachnoid drain

- **Effect of cerebrospinal fluid leak:**

  CORRELATION OF CEREBROSPINAL FLUID LEAK

  - VS SIZE OF THE PITUITARY ADENOMA AND
  - VS SUPRASELLAR EXTENSION OF THE PITUITARY TUMOUR

	Detail	CSF leak present	CSF leak absent	
		Number	Number	P value
size of pituitary adenoma	micro-adenoma	0	3 (8.33%)	
	macro-adenoma	10 (100%)	33 (91.67%)	**0.345**
suprasellar extension	present	7 (63.64%)	30 (76.92%)	
	absent	4 (36.36%)	9 (23.04%)	**0.375**

Table 13 – Correlation of cerebrospinal fluid leak vs size of the pituitary tumour and vs suprasellar extension of the pituitary tumour

Size of pituitary tumour (AP measurement) vs presence of cerebrospinal fluid leak at the end of surgery has a **P value = 0.345.**

The presence or absence of a suprasellar extension of the pituitary tumour had an insignificant effect on the presence of cerebrospinal fluid leak at the end of the surgery. **P value = 0.375**

- CEREBROSPINAL FLUID LEAK VS THE DURATION OF HOSPITALISATION:

Variable		Mean		S.D		P value
CSF leak present						
Days of hospitalisation		14.82		5.13		
						0.0031
CSF leak absent						
Days of hospitalisation		10.13		4.21		

Table 14 – Effect of presence or absence of cerebrospinal fluid leak on the days of hospitalisation

CSF = cerebrospinal fluid, S.D = standard deviation

***P value = 0.0031**

There is an increase in 4.69 days of hospitalisation among the patients who had a cerebrospinal fluid leak as compared to those patients who had no cerebrospinal fluid leak. This was found to be a significant finding with a * P value = 0.0031 (P value <0.05).

- **Effects on headache:**
  - VS DIFFICULTIES IN TAPPING THE LUMBAR SPACE
  - VS NUMBER OF ATTEMPTS FOR PLACING THE LUMBAR SUBARACHNOID DRAIN
  - VS NUMBER OF LEVELS ATTEMPTED FOR PLACING THE LUMBAR SUBARACHNOID DRAIN
  - VS TOTAL VOLUME OF CEREBROSPINAL FLUID DRAINED

	Variable	Headache present	Headache absent	P value
difficulties in tapping lumbar space	Yes	19 (90.48%)	6 (54.55%)	
	No	2 (9.52%)	5 (45.45%)	**0.032**
Number of attempts	1	2 (9.52%)	1 (12.5%)	
	2	8 (38.10%)	3 (37.5%)	
	3	8 (38.10%)	4 (50%)	**0.924**
	4	3 ((14.29%)	0	
Number of levels attempted	1	10 (47.62%)	6 (75%)	
	2	9 (42.86%)	2 (25%)	**0.44**
	3	2 (9.52%)	0	

Table 15 – Effect of difficulties in tapping lumbar space, number of attempts at placing the lumbar space and number of levels attempted at placement of lumbar subarachnoid drain vs headache

Difficulty in tapping the lumbar space, while performing a lumbar subarachnoid drain placement procedure, does have a significant effect on the presence of headache. This finding has a ***P value = 0.032** (P value <0.05).

The number of patients who developed headache after 1 attempt at lumbar drain placement was 9.52% whereas, the number of patients who developed headache after 2 attempts at lumbar drain placement was 38.10% and after 3 attempts was 38.10%.

However, the number of attempts at lumbar subarachnoid drain placement was not shown to have a significant effect on the symptom of headache for the patient.
The P value for this finding is 0.924**.**

The effect of the number of levels attempted at placement of the lumbar subarachnoid drain on headache has an insignificant P value = 0.44

- EFFECT OF TOTAL VOLUME OF CEREBROSPINAL FLUID DRAINED ON HEADACHE

Variable		Mean	S.D	P VALUE
Headache present				
total csf (ml)		83.71	57.02	
				0.479
Headache absent				
total csf (ml)		66.86	38.45	

Table 16 – Effect of total volume of cerebrospinal fluid drained on headache

P value = 0.479

It was observed that when a higher volume of cerebrospinal fluid was drained by the lumbar drain, the incidence of headache was higher. When a lesser volume of cerebrospinal fluid was drained by the lumbar drain, the incidence

of headache was found to be lesser. However, this finding was not statistically significant. P value = 0.479

- **Effects on backache:**
  - VS NUMBER OF ATTEMPTS FOR PLACING THE LUMBAR SUBARACHNOID DRAIN
  - VS NUMBER OF LEVELS ATTEMPTED FOR PLACING THE LUMBAR SUBARACHNOID DRAIN
  - VS DIFFICULTY IN CITING THE LUMBAR DRAIN CATHETER
  - VS TOTAL VOLUME OF CEREBROSPINAL FLUID DRAINED

	Variable	Backache present	Backache absent	P value
Number of attempts	1	2 (15.38%)	22 (59.46%)	
	2	1 (7.69%)	10 (27.03%)	
	>2	10 (76.92%)	5 (13.51%)	**0.000**
Number of levels attempted	1	5 (38.46%)	32 (86.49%)	
	2	6 (46.15%)	5 (13.51%)	**0.001**
	3	2 (15.38%)	0	
Difficulty in citing the catheter	Yes	6 (50%)	9 (45%)	
	No	6 (50%)	10 (50%)	**1**
	unable to thread	0	1 (5%)	

Table 17 – Effect of number of attempts for placing lumbar subarachnoid drain, number of levels attempted for placement of lumbar subarachnoid drain and difficulty in citing the lumbar drain catheter on backache

The number of attempts at lumbar drain placement have a very significant effect on the presence of backache for the patients. 76.92% of the patients had backache on attempting more than twice. The ***P value = 0** (P <0.05).

The number of lumbar levels attempted for lumbar drain placement has a very significant effect on backache for the patient. 46.15% of the patients developed backache as compared to 13.51% who did not develop backache, on attempting 2 levels for lumbar drain placement. 15.38% of the patients developed backache as compared to no patients without headache, on attempting 3 levels for lumbar drain placement. ***P value = 0.001 (**P value <0.05).

There was no significant effect of difficulty in citing the lumbar drain catheter on backache for the patient. The P value = 0.156.

- EFFECT OF TOTAL VOLUME OF CEREBROSPINAL FLUID DRAINED ON BACKACHE

Variable		MEAN	S.D	P VALUE
Backache present				
total csf (ml)		57.38	58.35	
				0.04
Backache absent				
total csf (ml)		82.95	45.7	

Table 18 – Effect of total volume of cerebrospinal fluid on backache

***P value = 0.04**

There is no incidence of backache when a higher volume of cerebrospinal fluid (82.95 ml) is drained by the lumbar subarachnoid drain. A higher incidence of backache is present among the patients when a lower volume (57.38 ml) of cerebrospinal fluid is drained by the lumbar subarachnoid drain.

*P value = 0.04 (P value <0.05)

DISCUSSION

DISCUSSION

Pituitary tumours are the commonest primary tumours of the central nervous system. The latest treatment of choice for these tumours is excision via the trans-nasal trans-sphenoidal approach. According to literature, the placement of a lumbar subarachnoid drain (LSAD), has been shown to reduce the intra-operative and post-operative cerebrospinal fluid leak and thus brings about a reduction in the overall morbidity associated with the surgery. However, the use of the LSAD is controversial and is infamous for causing its own complications. The routine LSAD system consists of a specifically designed, wire reinforced Codman's catheter. Owing to the high cost and unavailability of the specifically crafted LSAD equipment and Codman's catheter, we use the routine epidural kit and the standard epidural catheter that is available along with the kit. As a result, we tend to use sub-optimal equipment to perform the lumbar subarachnoid drain placement procedure due to unavailability of better alternatives.

This study brings out the fact that although lumbar subarachnoid drain placement is quite commonly performed by the anaesthesiologists, they often experience difficulties during the procedure. They also experience difficulty in drainage of cerebrospinal fluid with the use of nylon catheters, even after successful lumbar drain placement.

Hence, one of the objectives of this study was to assess the incidence of difficulties observed during lumbar subarachnoid drain placement with the epidural catheter kit. In our study, the majority of the LSADs were placed in intubated patients by using the midline approach to identify the subarachnoid space. Most studies do not mention whether the drain was placed after the patient was intubated or non-intubated except in the study by Mehta et al, where the drain was placed after the patient was intubated and in the study by Ransom et al, where the drain was placed during the surgery.

The anaesthesiologists who performed the lumbar drain procedure encountered difficulty in its placement in 64% of the patients included in the study. One of the reasons for difficulty in lumbar drain placement was the difficulty in tapping the lumbar space. This was observed in 78% of the patients, with 2 or more attempts required to successfully identify the space in 52% of the patients and attempts required at 2 or more lumbar levels in 26% of the patients to finally place the lumbar drain. Difficulty in citing the catheter was seen in 50% of the patients who had difficult lumbar drain placement. Difficulty in cerebrospinal fluid drainage was observed in 10% of the patients. However, in spite of all these difficulties the mean total volume of cerebrospinal fluid drained was found to be 76.3ml.

Manipulations had to be done in 10 cases of the 64% of the patients who had difficulty in placement of the lumbar drain, as there was decreased cerebrospinal drainage in 30 % of the patients and no drainage in 2% of the patients after positioning the patient in supine. The manipulations used by various anaesthesiologists to improve the cerebrospinal flow were sandbag placement in 22%, flushing of the catheter in 18%, flexion of the legs in 12% and pulling back the catheter in 10% of the patients. Hence the technical failure rate in our study is 2%, whereas the drain failure rate is 10%.

In the study by Adnan et al (56), fluoroscopy guided lumbar drain catheter placement was attempted in order to decrease the rate of technical difficulties and complications associated with lumbar drain placement as compared to the traditionally practised method of lumbar drain insertion by following the anatomical landmarks. In this study, the lumbar drain was placed for a variety of indications and was used only in one case of pituitary surgery. They used fluoroscopic guidance, large catheters (14 G), prone positioning in awake patients and the paramedian approach for all their lumbar drain procedures and yet they had a technical failure rate of 2.32% (1 of 43 patients).

Whereas we performed the lumbar drain placement procedure using anatomical landmarks as guidelines, a small catheter (18 G), lateral positioning in intubated patients, a 90% use of midline approach and yet had a technical failure rate of only 2% (1 of 50 patients).

In another study by Wynn et al (53), placement of lumbar subarachnoid drains using a smaller catheter (19G), anatomical landmarks as a guideline, needle insertion at the L3-L4 or L2-L3 interspace and catheter tip advanced 10cms beyond the dura was compared with the use of a larger catheter (16G), fluoroscopic guidance, needle insertion at the L3-L4 or L2-L3 and the catheter tip positioned at T9-T10. This study found the mean volume of cerebrospinal fluid drained by the use of a small catheter and a large catheter to be comparable. The mean volume of cerebrospinal fluid drained by the large catheter was 128ml whereas the in our study it was found to be 76.3ml. This could be because the lumbar drains are usually removed after completion of the surgery in most of the cases. The incidence of post dural puncture headache in small drains was found to be 0.6% whereas in large drains, it was 2.3%. None of our patients with headache demonstrated postural headache which would require an epidural blood patch. The rate of drain failure for small drains (19G catheters) was 7.8% and for large drains (16 G catheters) was 1.7%. Whereas in our study using 18 G (small) catheters, we found the drain failure rate to be 10%. This could be because of the fact that we used small drains with nylon catheters whereas, Wynn et al used large drains with silicone catheters, which have been demonstrated to be superior to nylon catheters (17).

Most anaesthesiologists have been observed to prefer using the Portex epidural kit for performing the lumbar drain procedure and choose Tegaderm with pad for fixation of the drain. All patients were observed to have received prophylactic antibiotics.

The surgeons were satisfied with the intraoperative conditions in 58% of the patients and found the intraoperative findings to be excellent in 26% of the patients. The surgeons'

satisfaction in comparison with the total volume of cerebrospinal fluid drained was found to be a very significant finding.

Another objective of this study was to assess the incidence of complications associated with pre-operative lumbar drain placement in endoscopic pituitary surgery. Among the major complications anticipated and assessed, only personal error and an increase in the duration of hospitalisation was observed.

Dressing changes and lumbar subarachnoid drain system changes were observed in 14% of the patients. However, there was no incidence of local infection or meningitis observed.

The presence of cerebrospinal fluid leak was seen to significantly increase the duration of hospitalisation by almost 4.69 days in the patients with a cerebrospinal fluid leak as compared to those with no cerebrospinal fluid leak. This is comparable with the findings of Jung et al, who observed the duration of hospitalisation to be 5.4+/-2.2 days for patients with a cerebrospinal fluid leak as compared to 3.5+/-1.9 days for patients with no cerebrospinal fluid leak.

Among the minor complications assessed and anticipated, only headache and backache were observed among the patients in the study. Headache was present in 56% of the patients who were included in the study. This is comparable to the findings by Kitchel et al, who found the incidence of headache in patients with lumbar subarachnoid drains to be 58%. However the incidence of headache in the study by Shapiro et al was found to be 63%. Difficulty in tapping the lumbar space during placement of a lumbar subarachnoid drain was found to have a significant effect on the presence of headache in the patients.

In the study by Wynn et al ,the incidence of post dural puncture headache in small drains (19 G catheters) was found to be 0.6% whereas in large drains (16G catheters), it was 2.3%. None of our patients with headache demonstrated postural headache which would require an

epidural blood patch. This is probably because the mean volume of cerebrospinal fluid drained by the large catheter was 128ml whereas the in our study it was found to be 76.3ml only. In concordance with this, we also found that in the subgroup of patients with headache, there was an insignificant but definite increase in the volume of CSF that was drained.

The incidence of backache was found to be 26% among the patients included in the study. The number of attempts at placing the lumbar subarachnoid drain and the number of levels attempted during the procedure were found to have a significant effect on the presence of backache in the patients. Although this is only a minor complication and is not reported by any other study, it is important when we consider the quality of care offered to the patient.

COMPARISON OF THE RATE OF INCIDENCE OF COMPLICATIONS

The rate of complications as observed in the study by Sloan et al and in our study were compared:

COMPLICATION	SLOAN ET AL %	OUR STUDY %
Post dural puncture headache	9.7%	0
Headache	0	56%
Intracranial hemorrhage	2.8%	0
Catheter fracture	0.2%	0
Meningitis	0	0
Epidural abscess	0	0
Hematoma	0	0

Table 19 – Comparison of the complication rates between the study by Sloan et al and our study

The study by Sloan et al was conducted on 504 patients whereas our study included only 50 patients. In our study, the lumbar drains were usually removed after the surgery was completed. The patient was observed up to 24 hours after completion of the surgery and hence, cases of post dural puncture headache occurring after the first 24 hrs could not be identified. For the first 24 hours, the patients were also kept in the supine position and this could be another reason for not observing any cases of post dural puncture headache in our study. The complication of backache was not assessed by Sloan et al.

We would like to conclude by affirming with Wynn et al that the rate of difficulty in lumbar drain placement is unacceptably high with the use of epidural catheters for the purpose of CSF drainage. Moreover, a drain failure rate of 10% after successful LSAD placement mandates that large drain catheters, specifically designed for CSF drainage, must be used.

Since the rate of technical failure is only 2%, in our study, the use of fluoroscopy as the first line of treatment for the placement of LSAD is questionable.

CONCLUSION

CONCLUSION

Anaesthesiologists face multiple difficulties in placement of the lumbar subarachnoid drain. Most of these could be attributed to the use of epidural catheters instead of the lumbar subarachnoid drain system and catheter.

In our study, we observed that the incidence of difficulties encountered in the placement of lumbar subarachnoid drains was 64%. Of these, we had difficulty in identifying the lumbar subarachnoid space in 78% and more than 52% required more than 2 attempts and about 26% required attempts at more than 2 levels for the identification of the lumbar subarachnoid space. After identifying the space, we had difficulty in citing the lumbar drain catheter in 46.88% of the patients and were not able to cite the catheter in 2% of them.

After successful drain placement and confirmation of adequate cerebrospinal fluid flow, yet another 30% had difficulty in cerebrospinal fluid drainage after positioning the patient in the supine position. Despite using multiple manipulations to improve the cerebrospinal fluid flow rate, one-third of these patients still continued to have difficulty in cerebrospinal fluid drainage intraoperatively, leading to a 10% drain failure rate.

We observed the incidence of headache to be 56% and backache to be 26%.

The presence of headache was observed to have an increasing trend in the presence of an increase in the volume of cerebrospinal fluid drained by the lumbar subarachnoid drain. However, there was no incidence of postural headache which would require an epidural blood patch. The presence of backache was significantly related to the number of attempts and number of levels required to place the lumbar subarachnoid drain.

Although lumbar subarachnoid drain placement for pituitary surgery is associated with only minimal complications, there is an unacceptably high rate of difficulties in placement and lumbar subarachnoid drain failure rates.

LIMITATION

LIMITATION

- The estimated sample size of 183 could not be achieved and an interim analysis had to be done with 50 patients.

- Our post-operative follow up for the patients lasted only for 24 hours after lumbar drain removal. Hence, postural headache developing after 24 hours was not assessed.

- Owing to the unavailability of specifically designed large subarachnoid drains such as the Codman's drain and the Medtronic drain, we could not compare the incidence of technical difficulties and complications between them and the epidural catheter.

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ANNEXURE

PROFORMA

Title of Research: Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical

difficulties and complications – A prospective observational study

Study No: Date:

Name: Age: Sex: M/F Hospital Number:

Weight: Height: BMI:

Date of admission: Date of discharge:

Duration of hospital admission:

Diagnosis:

Planned Surgery:

Size of the pituitary :

Presence of any suprasellar extension: Yes / No

Co morbidities:

Any previous history of having undergone LSAD/ EVD/PITUITARY SURGERY : Yes /No

Any coagulation parameters available: Yes /No

Any previous history of meningitis : Yes / No

Investigations

Any prior positive CSF culture reports : Yes / No

Any prior positive blood /urine/sputum/wound cultures : Yes / No

CSF cell counts ,if done :

Total WBC Count : Differential WBC count :

INTRAOPERATIVE DATA

Placement -

LSAD placement done in : intubated / non-intubated patient

Technique of LSAD placement - midline / paramedian

Experience of the operator in Anaesthesiology (in years) :

Any difficulties encountered during placement of the LSAD – Yes / No

If yes ,

 Difficulty in tapping the lumbar space (>1 attempt />1 level) : Yes / No

No of attempts –

No of levels attempted-

 Difficulty in citing the catheter (> 1 attempt/ any manipulation) : Yes /No /unable to thread

 Difficulty in drainage of CSF after placement : Yes /No

 If yes, any manipulation done to improve the flow rate: Yes/No

Type of Lumbar drain (Epidural Kit) used

 Portex Braun Others

Fixation of the Lumbar drain

 Tegaderm with pad Plain Tegaderm with gauze Lock it plus Other techniques

After positioning –

 Any change in flow after positioning: Same drainage / decreased drainage / no drainage

 If drainage is reduced/ no drainage; Whether any manoeuvres were used to improve flow:

1. Pulling back the catheter: Yes / No

2. Sandbag placement: Yes / No

3. Flushing: Yes / No

4. Flexion of the legs: Yes/No

Total amount of CSF drained at the end of surgery -

(Please measure with a sterile 50 cc syringe in a sterile manner)

At the end of the surgery -

Surgeons satisfaction with intraoperative conditions: poor / satisfied / excellent

Presence of CSF leak at the end of the surgery: Yes / No

Catheter: left in situ / removed

Antibiotics administered intra-op (with dose) :

POSTOPERATIVE DATA

1. Insufficient CSF drainage : Yes / No

2. Presence of CSF leak from LSAD - Yes/ No

3. LSAD disconnection – Yes / No

4. Dressing changes done for the LSAD - Yes / No

5. LSAD system changes after initial placement – Yes / No

6. Retained catheter : Yes / No

7. Presence of nerve root irritation/ neuralgia : Yes / No

8. Presence of erythema / purulence / induration/haematoma at the site of LSAD insertion : Yes / No

9. Meningitis in the postoperative period: Yes/No

10. Antibiotics used in the postoperative period (with dose) :

11. Presence of back ache: Yes / No

12. Presence of low pressure headache: Yes / No

13. Others:

CONSENT TO TAKE PART IN A CLINICAL TRIAL

Lumbar subarachnoid drains for CSF drainage in pituitary surgery: Technical difficulties and complications – A prospective observational study

Study Number:

Participant's name:

Date of Birth / Age (in years):

I_____

_____, son/daughter of _____

(Please tick boxes)

Declare that I have read the information sheet provide to me regarding this study and have clarified any doubts that I had. [ ]

I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]

I understand that I will receive free treatment for any study related injury or adverse event but I will not receive any other financial compensation [ ]

I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access. However, I understand that my identity will not be revealed in any information released to third parties or published. [ ]

I understand that my identity will not be revealed in any information released to third parties or published [ ]

I voluntarily agree to take part in this study [ ]

Name:

Signature:

Date:

Name of witness:

Relation to participant:

Date:

Study Investigator's Name:

Signature of the Investigator:

Date

CHRISTIAN MEDICAL COLLEGE, VELLORE

DEPARTMENT OF ANAESTHESIOLOGY

Title of Research: Lumbar subarachnoid drains for CSF drainage in pituitary surgery : Technical difficulties and complications – A prospective observational study

Patient Information Sheet

Dear Sir/Madam,

You are requested to participate in a study to determine the problems faced while placing a lumbar sub-arachnoid drain (LSAD) and its associated complications. Most patients who undergo trans-nasal trans-sphenoidal surgery benefit from the placement of a LSAD. In our institution, all patients of Neurosurgery unit 1, who undergo trans-nasal trans-sphenoidal surgery, routinely undergo LSAD placement during the surgery. By this study, we aim to identify the problems faced during placement of the LSAD and the complications that may arise from it in the post-operative period.

Will you be subjected to invasive procedures under this study?

All patients of Neurosurgery unit 1, who undergo trans-nasal trans-sphenoidal surgery, routinely undergo LSAD placement during the surgery. The information for this study will be obtained during this routine process. No new invasive procedures will be done for this study.

If you take part, what will you have to do?

If you agree to take part in this study, we will collect your medical information before the surgery, record details regarding placement of the LSAD during the surgery and any complications that may occur during after the surgery.

Can you withdraw from this study after it starts?

Your participation in this study is entirely voluntary. You are free to decide on withdrawing your permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

What will happen if you develop any study related injury?

We do not expect any injury related to the study as the study itself only involves collection of your medical history and details regarding the routine procedure that you will undergo during surgery.

Will your personal details be kept confidential?

If you agree to participate in this study, you will be allotted a specific study number. The name and other personal details of the study participants will be available only with the primary investigator, kept securely. The results of this study will be published in a medical journal but you will not be identified by name in any publication or presentation of results. However, your medical notes may be reviewed by people associated with the study, without your additional permission, should you decide to participate in this study.

slno	date	name	age	sex	hospno	wt	ht	bmi	doa	dod	dayshosp	diagnosis	surgery	sizepitu	sizepitutr	sizepitucc	supraslr	dm	htn	ihd	asthn
1	########	haneefa b.	41	1	622436f	83	162	31.6	########	########	8	1	1	30	30	26	1	2	2	2	
2	########	padmini e.	36	2	532686g	75	165	27.5	########	########	26	1	1	8	5	9	2	1	1	2	
3	########	bimla devi	57	2	713174g	53	147	24.5	########	########	10	1	1	30	25	25	1	1	2	2	
4	########	s.m. zahir	34	1	742339g	80	174	26.4	########	########	10	1	1	30	26	16	1	2	2	2	
5	########	nantu das	43	1	716496g	62	160	24.2	########	########	11	1	1	36	22	31	2	2	2	2	
6	########	muthuvel	60	1	447566a	89	162	33.9	########	########	13	1	1	12	10	7	2	2	2	2	
7	########	arjun pras	53	1	761110g	70	166	25.4	########	########	15	1	1	25	25	20	1	2	2	2	
8	########	anandhi	41	2	374019g	65	155	26.2	########	########	20	1	1	20	24		1	1	1	2	
9	########	hasina beg	31	2	753849g	76	150	33.3	########	########	23	1	1	22	13	12	2	1	1	2	
10	########	prem prad	37	1	097238g	82	171	28	########	########	11	1	1	19	19	20	1	2	2	2	
11	########	nirmala de	46	2	699207g	43	154	18	########	########	14	1	1	14	14	16	2	1	1	2	
12	########	santosh ku	33	1	701130g	87	167	31.2	########	########	7	1	1	9.5	9.5		2	1	2	2	
13	########	priyanka n	24	2	759900g	72	161	27.8	########	########	10	1	1	31	19	19	1	1	2	2	
14	########	mohamme	49	1	732094g	741	64	27.5	########	########	13	1	1	28	29	23	1	2	1	2	
15	########	elius begu	31	2	711370g	60	161	23.1	########	########	19	1	1	18	14.4		1	2	2	2	
16	########	nilam devi	43	2	752216g	76	158	30.2	########	########	14	1	1	33	21	15	1	1	2	2	
17	########	selvi t.	53	2	523826g	60	149	27	########	########	3	2	2				2	2	2	2	
18	########	meesala b	38	1	439187g	80	174	26.4	########	########	13	1	1	37	28		1	2	2	2	
19	########	panna ran	38	2	781226g	45	155	18.7	########	########	10	1	1	31	30	21	1	2	2	2	
20	########	sukramani	26	1	806621g	70	165	25.7	########	########	14	1	1	27	35	33	1	2	2	2	
21	########	shahabud	39	1	747442g	85	166	30.8	########	########	11	1	1	22	21	25	1	2	2	2	
22	########	shaik mee	57	1	759316g	65	170	22.5	########	########	20	1	1	23	26	29	1	2	2	2	
23	########	saidur rah	26	1	791507g	89	175	29	########	########	8	1	1	10	13	13	1	2	2	2	
24	########	mohan da	53	1	785055g	60	171	20.5	########	########	5	1	1	32	30	31	1	1	2	2	
25	########	guruprasa	28	1	752762g	65	171	21.2	########	########	11	1	1	13	7		2	2	2	2	

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
24	########	mohan da	53	1	785055g	60	171	20.5	########	########	5	1	1	32	30	31	1	1	2	2	
25	########	guruprasa	28	1	752762g	65	171	21.2	########	########	11	1	1	13	7		2	2	2	2	
26	########	jayavelu	72	1	292289d	65	170	22.5	########	########	7	1	1	32	3	28	1	2	2	2	
27	########	sajida khat	54	2	821399g	59	150	26.2	########	########	11	1	1	25	7	39	1	1	2	2	
28	########	devasagay	76	1	605990a	68	160	26.6	########	########	12	1	1	22	21	19	1	2	1	2	
29	########	hamsaven	51	2	744729a	70	161	27	########	########	18	1	1	27	28	38	1	1	1	2	
30	########	salma s.	38	2	514323f	65	161	25.1	########	########	10	1	1	20	18	16	1	1	1	2	
31	########	jawahar la	65	1	819647g	71	152	30.7	########	########	8	1	1	37	30	32	1	2	2	1	
32	########	muniamm	47	2	545252g	68	152	29.4	########	########	10	1	1	15	15	20	1	1	1	2	
33	########	kalimuthu	36	1	863205g	51	166	18.5	########	########	5	1	1	24	25	33	1	2	2	2	
34	########	mst taslim	39	2	793242g	77	162	29.3	########	########	6	1	1	36	38	40	1	2	1	2	
35	########	gudiya dev	26	2	547791g	64	149	28.8	########	########	10	1	1	33	31	25	1	2	2	2	
36	########	mohamme	3	1	671324g	99	184	29.2	########	########	5	1	1	27	17	16	1	1	2	2	
37	########	khairul nes	43	2	834921g	70	155	29.1	########	########	15	1	1	24	18	26	1	1	2	2	
38	########	shambu sh	40	1	816512g	60	162	22.9	########	########	7	1	1	16	18	20	1	2	2	2	
39	########	yirga zelal	56	1	922453g	68	160	26.6	########	########	13	1	1	20	26	27	1	2	1	2	
40	########	shefali kar	51	2	838857g	82	157	33.3	########	########	13	1	1	28	24	30	1	1	1	2	
41	########	krishna pra	31	1	846125g	62	161	23.9	########	########	10	1	1	30	30	20	1	2	2	2	
42	########	hemavath	49	2	111213f	71	147	32.8	########	########	6	2	2				2	1	1	2	
43	########	utsav	16	1	506460g	56	180	17.3	########	########	7	2	2				2	2	2	2	
44	########	sushila ran	61	2	840647g	49	143	24	########	########	11	1	1	16	20	14	1	1	1	2	
45	########	tariq moha	32	1	951424g	110	186	31.8	########	########	13	1	1	20	26	21	1	2	2	2	
46	########	mukesh ya	23	1	807436g	80	173	26.7	########	########	6	1	1	25	22	23	1	2	2	2	
47	########	khaleda ah	34	2	957709g	79	154	33.3	########	########	6	2	2				2	2	2	2	
48	########	jose joseph	64	1	924091g	54	178	16.9	########	########	8	1	1	22	24	33	1	2	2	2	
49	########	manoj sub	37	1	894747g	62	160	24.2	########	########	14	1	1	16	10	10	2	2	2	2	
50	########	muniamm	48	2	545252g	64	153	27.3	########	########	8	1	1	15	15	20	2	1	1	2	

V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
asthma	copd	ckd	hypothy	hypopitu	othcomor	prevhist	coagul	coagrest	prevmenir	csf	bldcult	urinecult	woundcult	csfcell	wbccount	neutro	lympho	eosino	basophils	monocyte	ls
2	2	2	2	1		1	2		2	2	2	2	2		11000	67	22	5	0	6	
2	2	2	1	2		2	2		2	2	2	2	2		11700	83	10	1	0	6	
2	2	2	2	2		2	2		2	2	2	2	2		11900	56	32	2	0	10	
2	2	2	2	2		2	2		2	2	2	2	2								
2	2	2	2	1		2	2		2	2	2	2	2		10300	62	27	3	0	8	
2	2	2	2	2	psychiatric	2	2		2	2	2	2	2		7000	66	24	2	0	8	
2	2	2	2	2		2	2		2	2	2	2	2								
2	2	2	2	2		2	1	1	2	2	2	2	2		9800	76	16	0	11	8	
2	2	2	2	2	obesity	2	2		2	2	2	2	2		11100	66	26	0	0	8	
2	2	2	1	1		2	1	1	2	2	2	2	2		10700	84	11	1	0	4	
2	2	2	2	2		2	2		2	2	2	2	2		4800	64	27	2	0	7	
2	2	2	2	2		2	1	1	2	2	2	2	2		6800	53	36	5	0	6	
2	2	2	2	2		2	2		2	2	2	2	2		6800	41	45	4	0	10	
2	2	2	2	2		2	2		2	2	2	2	2		9900	38	49	2	0	11	
2	2	2	2	2		2	2		2	2	2	2	2		8100	61	30	2	0	7	
2	2	2	1	2	seizure dis	2	2		2	2	2	2	2								
2	2	2	2	2		2	2		1	1	1	2	2		7600	67	19	2	1	11	
2	2	2	2	2		2	2		2	2	2	2	2		5800	53	42	1	0	4	
2	2	2	1	1		2	2		2	2	2	2	2		4700	42	46	2	0	10	
2	2	2	2	2		2	2		2	2	2	2	2		14600	60	31	4	1	4	
2	2	2	2	2		1	2		2	2	2	2	2		6200	43	39	6	0	12	
2	2	2	1	1		2	2		2	2	2	2	2		8400	41	45	5	1	8	
2	2	2	2	2		2	2		2	2	2	2	2								
2	2	2	1	2		2	2		2	2	2	2	2		8200	51	40	1	0	8	
2	2	2	2	2		2	2		2	2	2	2	2		6500	68	18	4	0	10	
2	2	2	1	2		2	2		2	2	2	2	2		8500	63	27	2	0	8	

V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
2	2	2	2	2		2	2		2	2	2	2	2							
2	2	2	1	2		2	2		2	2	2	2	2		8200	51	40	1	0	8
2	2	2	2	2		2	2		2	2	2	2	2		6500	68	18	4	0	10
2	2	2	1	2		2	2		2	2	2	2	2		8500	63	27	2	0	8
2	2	2	1	2		2	2		2	2	2	2	2		12700	77	19	1	0	3
2	2	2	2	2		2	2		2	2	2	2	2		8200	62	27	2	0	9
2	2	2	1	2		2	2		2	2	2	2	2		7400	55	32	4	0	9
2	2	2	1	2		2	2		2	2	2	2	2							
2	2	2	2	2		2	2		2	2	2	2	2		8200	65	23	2	0	10
2	2	2	2	2		2	2		2	2	2	2	2		12300	67	26	1	0	6
2	2	2	1	1		2	2		2	2	2	2	2		7400	40	48	4	0	8
2	2	2	2	2	klippel feil	2	2		2	2	2	2	2							
2	2	2	2	1		2	2		2	2	2	2	2		10500	48	43	2	0	7
2	2	2	2	2		2	2		2	2	2	2	2		5400	47	43	2	0	8
2	2	2	2	2		2	1	1	2	2	2	2	2		6900	69	23	0	0	8
2	2	2	2	2		2	2		2	2	2	2	2		7900	51	42	2	0	5
2	2	2	1	2		2	2		2	2	2	2	2		6700	42	44	3	1	10
2	2	2	2	2		1	2		2	2	2	2	2							
2	2	2	2	2		2	2		2	2	2	2	2							
2	2	2	2	2		2	2		2	1	2	2	2	1	12800	81	10	0	0	9
2	2	2	2	2		1	1	1	2	2	2	2	2		7900	58	29	9	0	7
2	2	2	2	2		2	2		2	2	2	2	2		8100					
2	2	2	2	2		2	2		2	2	2	2	2		7200	56	28	5	0	11
2	2	2	1	2		2	2		2	2	2	2	2		8600	39	49	7	0	5
1	2	2	1	2		2	2		2	2	2	2	2	2	10800	57	37	1	0	5
2	2	2	2	1		2	2		2	2	2	2	2		5400	40	38	6	0	16
2	2	2	2	2		2	2		2	2	2	2	2		8300	50	35	8	0	7

AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
1	1	1	1	1	2	1	2	2	2	1	1	1	2	2	2	2	100
1	1	1	2							1	1	1	2	2	2	2	120
1	2	6	1	2	1	1	2	1	1	1	1	3	1	2	1	1	0
1	1	3	2							1	1	2	2	1	2	2	95
1	1	3	1	2			2	1	1	2	2	2	2	1	2	2	75
1	1	2	2							1	1	2	1	1	2	2	100
1	1	2	1	1	3	2	1	1	1	1	1	2	2	1	1	1	30
1	1	3	2							1	1	2	2	1	2	1	40
1	1	20	1	2			1	2	2	1	1	1	2	2	2	2	100
1	1	2	2							1	1	1	2	2	2	2	75
1	2	20	1	1	2	1	2	2	2	1	1	1	2	2	2	2	80
1	1	2	1	1	4	2	1	2	1	1	1	1	2	2	2	2	76
1	1	2	1	1	2	1	1	1	1	1	1	2	2	1	1	1	30
1	1	12	1	2			3	1	1	1	1	2	1	1	2	1	100
2	1	10	1	1	3	1	2	2	2	1	2	2	1	2	1	2	30
1	1	2	2							1	3	1	2	2	2	2	100
1	1	2	2							1	3	1	2	2	2	2	200
1	2	10	1	1	4	2	1	2	2	3	1	1	2	2	2	2	2
2	2	12	1	1	3	3	1	1	2	2	1	1	2	2	2	2	60
1	1	1	2							1	3	1	2	2	2	2	100
1	2	13	1	1	3	2	1	2	2	1	1	1	2	2	2	2	165
1	1	8	2							3	1	1	2	2	2	2	100

AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI
8	1	1	8	2							3	1	1	2	2	2	2	100	2
10	2	1	8	1	1	3	2	2	1	1	1	1	2	2	1	1	2	3	1
8	1	1	8	1	2	3	1	1	2	2	1	1	1	2	2	2	2	55	3
3	1	1	1	2							1	1	1	2	2	2	2	120	2
9	1	1	9	2							1	1	1	2	2	2	2	34	1
9	1	1	9	1	1	2	1	2	2	2	1	1	2	2	2	1	2	50	2
	1	1	2	1	1	3	2	2	2	2	1	1	1	2	2	2	2	75	3
10	1	1	3	1	1	3	2	2	2	2	1	1	1	2	2	2	2	75	3
6	1	1	10	1	1	3	1	2	1	1	1	1	1	2	2	2	2	45	2
8	1	1	1	1	1	2	1	1	2	2	1	1	1	2	2	2	2	60	3
	1	1	1	2							1	1	1	2	2	2	2	35	3
7	1	1	1	1	1	2	1	1	2	2	1	2	2	2	2	1	2	13	2
8	1	1	2	2							1	1	1	2	2	2	2	120	3
8	1	1	3	2							1	1	1	2	2	2	2	50	3
5	1	1	3	2							2	1	1	2	2	2	2	105	3
10	1	1	3	2							1	2	1	2	2	2	2	200	2
	1	1	3	2							1	1	2	2	1	2	2	10	2
	1	1	10	1	2	1	1	2	1	1	1	1	2	1	1	1	2	30	2
9	1	1	7	1	1	2	1	1	2	2	1	3	1	2	2	2	2	100	3
7	1	1	2	1	1	2	1	2	2	2	1	1	1	2	2	2	2	100	2
	1	1	10	1	1	3	2	1	2	2	1	1	1	2	2	2	2	40	1
11	1	1	5	1	1	2	1	2	2	2	1	3	1	2	2	2	2	175	2
5	1	1	2	1	2	1	1	1	2	2	1	3	1	2	2	2	2	125	2
5	1	1	3	1	1	4	3	2	2	2	1	1	1	2	2	2	2	50	2
16	1	1	8	1	1	3	2	2	2	2	1	1	1	2	2	2	2	175	2
7	2	1	10	1	1	2	2	1	1	1	1	1	2	2	1	1	1	7	1

BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC
surgeons	csfleak	catheter1	antibiotic	othanti	antidose	csfdrain	csflsad	lsaddis	dresslsad	lsadinit	retaincath	nerveroot	erythema	meningiti	antibioti1	othantipo	antidosep	backache	headache	others
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
2	1	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
1	2	2	1		2	1	2	2	2	2	2	2	2	2				1	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
2	1	1	1		2	2	2	2	1	1	2	2	2	2	1		2.1	2	2	
1	1	1	1		2	1	2	2	1	1	2	2	2	2	1		2	1	2	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
3	2	1	1		2	2	2	2	2	2	2	2	2	2				2	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				1	1	
1	1	1	1		2	2	2	2	1	1	2	2	2	2	1		2	2	1	
2	1	1	1		2	2	2	2	1	1	2	2	2	2	1		2	2	2	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				1	2	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
1	1	1	1		2	2	2	2	1	2	2	2	2	2	1		2	1	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				1	1	
2	1	1	1		2	2	2	2	1	1	2	2	2	2	1		2	2	1	
3	2	1	1		2	2	2	2	2	2	2	2	2	2				1	1	
2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
1	1	1	1		2	1	2	2	2	1	2	2	2	2	1		2	1	2	

	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC
27	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
28	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
29	1	1	1	1		2	1	2	2	2	2	2	2	2	2	1		2	2	1	
30	2	2	1	1		2	2	2	2	2	2	2	2	2	2				2	1	
31	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
32	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
33	2	2	2	1		2	2	2	2	2	2	2	2	2	2				1	1	
34	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
35	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
36	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
37	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
38	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
39	3	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
40	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
41	2	2	2	1		2	2	2	2	2	2	2	2	2	2	2	augmenti	1.2	1	2	
42	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	
43	3	1	1	1		2	2	2	2	2	2	2	2	2	2	1		2	1	1	
44	2	2	1	1		2	2	2	2	2	2	2	2	2	2	1		2	2	2	
45	1	2	1	1		2	2	2	2	2	2	2	2	2	2	1		2	2	1	
46	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
47	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	1	
48	2	2	1	1		2	2	2	2	2	2	2	2	2	2	1		2	1	1	
49	2	2	2	1		2	2	2	2	2	2	2	2	2	2				1	1	
50	1	1	1	1		2	1	2	2	1	1	2	2	2	2	1		2	2	1	
51	2	2	2	1		2	2	2	2	2	2	2	2	2	2				2	2	

ABBREVIATIONS

- CSF – cerebrospinal fluid
- LSAD – lumbar subarachnoid drain
- BMI – body mass index
- S.D – standard deviation