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Cerebrospinal fluid

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ABSTRACT: Cerebrospinal fluid is a highly specialised fluid that plays a key role in maintaining the health of the central nervous system. While collection is not without risk, the evaluation of this fluid can aid in diagnosing a variety of neurological conditions and gives a useful overview of the general status of the central nervous system. By understanding the risks of this procedure combined with correct handling, veterinary nurses are much better equipped to reduce complications whilst enhancing potentially critical patients' recovery.

KEYWORDS: cerebrospinal; CSF; neurology; spinal cord; central nervous system; epilepsy; meningitis; hydrocephalus

Introduction

Cerebrospinal fluid (CSF) collection, or "tap", is an important diagnostic tool in veterinary medicine used to identify a number of neurological conditions. CSF collection itself involves entering a body cavity, and therefore cannot be performed by a registered veterinary nurse under Schedule 3 of the Veterinary Surgeon's Act 1966. However, the veterinary nurse will still play an important role in the preparation, collection and processing of a CSF sample.

CSF is a clear, colourless bodily fluid that surrounds the central nervous system (CNS) and fulfils a number of key roles similar to those of blood in the rest of the body. The CNS is composed of the brain and the spinal cord. The entirety of the CNS is surrounded by the meninges, three layers of protective tissue: the dura mater, the arachnoid mater and the pia mater. CSF originates from blood plasma and is produced by specialised groups of cells, called choroid plexuses, in the ventricular system of the brain. From here it travels through the ventricular system into a space between the arachnoid mater and the pia mater known as the subarachnoid space. Once it has circulated the brain and travelled around the spinal cord in the subarachnoid space it is then reabsorbed into the bloodstream by arachnoid villi in the venous sinuses.

CSF composition is similar to that of blood plasma, containing a variety of electrolytes but virtually no proteins or blood cells. A small number of white blood cells (WBCs) are considered normal, but erythrocytes are not usually found in CSF.

Roles of CSF

CSF's protective roles include cushioning the CNS by acting as a shock absorber in the case of injury and allowing the brain to "float" in the skull so that cerebral blood flow is not impaired by the brain's own weight. It also transports important substances from plasma to the brain and spinal tissues, such as nutrients, metabolites and electrolytes. These are all filtered from blood plasma into CSF by the choroid plexuses, where they are then delivered to CNS cells and tissues whilst simultaneously removing waste produced by CNS cell metabolism. Neurotransmitters and neurohormones are also transported within CNS parenchyma via CSF.

CSF production is an active process: normal production is 0.047 ml/min in dogs and 0.017 ml/min in cats (de Lahunta, Glass, & Kent, 2014). Reabsorption is a passive process that occurs when the pressure of the CSF in the subarachnoid space exceeds that of the venous hydrostatic pressure in the bloodstream.

This passive process of reabsorption allows for CSF's important role in helping to regulate intracranial pressure (ICP). The closed cavity nature of the cranium means that any increases in pressure put cerebral parenchyma at risk of trauma. The three main constituents of the cranium are the CSF (10%), arterial and venous blood (10%) and the cerebral parenchyma and brain itself (80%) (Dos Santos, Caldas, Santos & Junior, 2018). If there is an increase in volume, such as in the case of cerebral oedema or haemorrhage, then this must be compensated for with a decrease in another component in order

to keep ICP within normal limits. As the body's homeostatic requirements are to preserve cerebral blood flow, CSF will be the first component to decrease in volume as the increased ICP will subsequently increase the rate of passive reabsorption.

If this first compensatory mechanism fails, then CSF production in the choroid plexuses will also decrease (Platt & Olby, 2013). Following this, any further increases in ICP will compromise cerebral blood flow and damage cerebral parenchyma, triggering clinical signs such as decreased mentation, miosis, limb extensor rigidity or opisthotonus.

Hydrocephalus

Hydrocephalus is the condition in which there is an accumulation of CSF in the subarachnoid space; this can put pressure on the cerebral parenchyma and subsequently cause neurological clinical signs. This CSF accumulation is most commonly caused by an obstruction of natural CSF flow, typically due to congenital abnormalities or neoplasia in the spinal cord.

CSF collection

Collection of CSF is performed in a number of clinical situations in order to analyse the cellularity and protein content of the fluid. This analysis of a CSF sample, in isolation, will rarely produce a definitive diagnosis. CSF analysis to the CNS can be compared to a complete blood count to the systemic circulation; a useful diagnostic tool to support and assist in reaching a definitive diagnosis (Dewey & da Costa, 2015). Alternatively, idiopathic epilepsy is a common neurological disease with a diagnosis of exclusion, and so analysing a CSF sample is important in excluding other infectious or inflammatory causes in order to reach the definitive diagnosis (Gonçalves, Anderson, Innocent & Penderis, 2010).

Most CNS diagnoses will benefit from a CSF tap: encephalopathies, spinal cord lesions, inflammatory diseases and myelopathies. These will alter CSF composition, while infectious diseases may lead to the addition of antibodies or bacteria in the CSF. No immunosuppressive medication should be administered prior to a CSF tap as this is likely to affect the results; while it may improve the patient's clinical signs, it will prevent a diagnosis from being made, and should be reserved for after sample collection.

Once collected, analysis of CSF will include an assessment of appearance, a nucleated cell count (NCC) and a determination of protein levels. CSF is usually clear and colourless; any turbidity would be considered abnormal (see Figure 1). Automated analysers such as those found in practice are not accurate with low-cellularity fluids such as CSF, so a manual NCC must be undertaken with a haematocytometer (Garland, 2012). This must usually be completed within 30 minutes of sample collection, otherwise the cells will begin to degrade and the count will not be genuine (Newton, Fry, & Best, 2017). Alternatively, the samples can be frozen to preserve cellularity and transported to an external laboratory for analysis.

Figure 1. High cellularity fluid collected from a cisternal CSF tap; this dog had neutrophilic meningitis.

CSF analysis is a highly sensitive test, but unfortunately it is not very specific. Elevated WBCs in CSF, defined as pleocytosis, can indicate an active infectious or inflammatory process in the CNS, but the ability to further differentiate between further diseases is not currently possible. Elevated protein levels suggest a breakdown in the blood–brain barrier, allowing additional protein into the CSF from the systemic circulation. This can be due to neoplasia, haemorrhage, inflammation or a blockage. Rarely, infectious agents may be identified on microscopic analysis of CSF.

How do we collect CSF?

There are two sites from which CSF can be collected in veterinary medicine: the cerebromedullary cistern or the lumbosacral articulation. Prior to stressing the patient with intravenous catheter placement, or subduing them with analgesia, localisation of the disease should be ascertained from a full neurological examination. This will then determine the decision of whether to undertake a cisternal or lumbar CSF tap, as CSF composition will be altered most dramatically (and therefore more likely to be of diagnostic value) at the collection site caudal to the lesion. Alternatively, if the CNS disease is suspected to be diffuse or multifocal then samples may be taken from both sites.

As a rule, it is safe to collect 1 ml of CSF per 5 kg of bodyweight (Platt & Olby, 2013). Fluid should be collected in both ethylenediaminetetraacetic acid (EDTA) and serum tubes; EDTA samples are better for examining cell morphology, but can cause falsely elevated protein levels (Dewey & da Costa, 2015). Samples in serum tubes allow protein analysis and can also be cultured for evidence of bacterial infection or submitted for polymerase chain reaction analysis for infectious disease. Equipment required for CSF collection is outlined in

Figure 2. Equipment required for CSF sampling. This includes: clippers, surgical preparation solution, sterile gloves, collection tubes and a spinal needle (20 or 22 gauge, 1.5 inches in cats and smaller dogs or 3.5 inches in larger dogs).

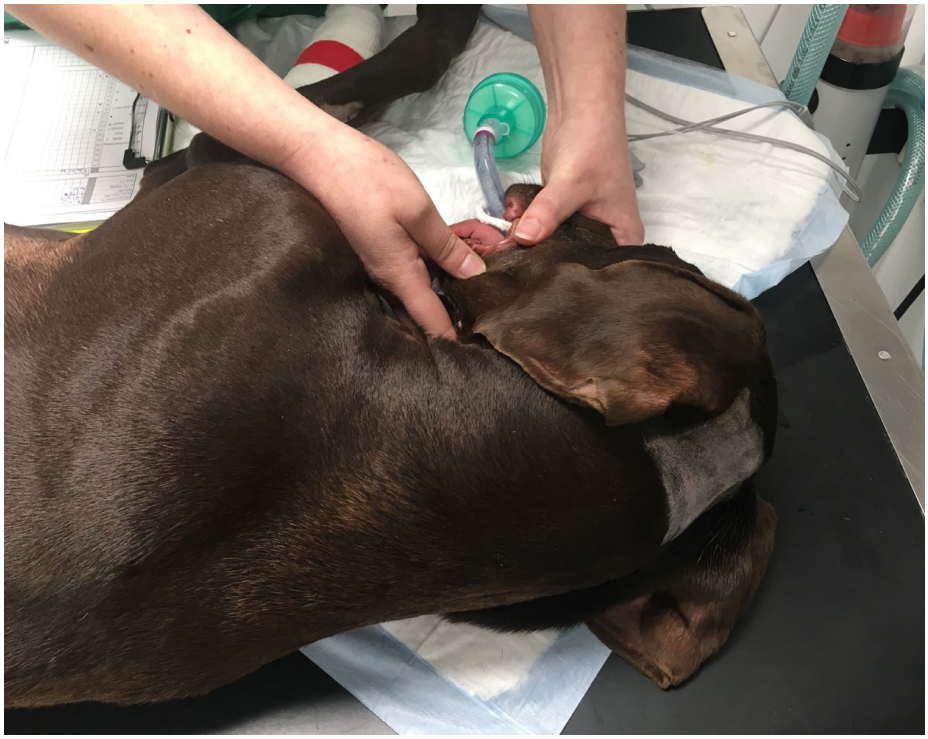

Figure 3. Positioning for a cisternal CSF sample. Note the extreme flexion of the neck, which may cause occlusion of the airway and endotracheal tube.

Figure 2. If myelography is planned then CSF collection should be performed prior to this, as the contrast medium will also be injected into the subarachnoid space and may alter the results.

Once the spinal needle has been inserted by the veterinary surgeon (VS), CSF will flow passively from the needle. It should never be aspirated with a syringe or via negative pressure; this can cause a rapid decrease in CSF, and subsequently ICP, which may potentiate intracranial haemorrhage or herniation. Tubes should instead be held underneath the spinal needle to allow a passive flow of CSF out of the subarachnoid space for collection. Once the sampling has been completed and the spinal needle removed, a few drops of CSF will remain in the spinal needle and can be collected by re-inserting the stylet.

Iatrogenic blood contamination of samples should be avoided as this can affect the results of the NCC. However recent studies suggest that, provided erythrocyte counts do not exceed 210,000 RBC/µl, an elevated NCC would be considered clinically significant despite blood contamination (MacNeill, Andre, Zengale, Packer & McGrath, 2018).

A general anaesthetic is required for all CSF collection. This is to ensure that the patient remains completely still throughout the procedure, as the spinal needle is extremely close to the spinal cord and any movement will put the patient at risk of spinal cord damage. Aseptic technique is highly recommended for collection, with the collection site clipped and cleaned in an aseptic manner akin to preparation for a surgical procedure. The VS should wear sterile gloves and maintain asepsis while performing the tap.

Cisternal CSF

The cerebromedullary cistern is located caudal to the cerebellum, with the needle puncture site located on the dorsal surface of the neck. Cisternal CSF samples are the most common in veterinary medicine as they are considered easier to perform and often produce a larger volume of CSF. It is recommended to deflate the cuff of the patient's endotracheal tube prior to positioning to avoid any damage to the tracheal mucosa.

Landmarks for needle insertion, and therefore clipping and surgical preparation of the insertion site, are the occipital protuberance at the back of the skull and the lateral aspects of the wings of the atlas (C1). The protuberance and two wings should be palpated with three fingers to make a triangle, the centre of which can be assumed to be the needle insertion point. A small square of fur should be clipped – the width of the clipper blades can be used as a guide, although if uncertain it is always better to clip a larger area. This area should then be cleaned and prepared aseptically with an appropriate surgical scrub solution.

The patient should be placed in lateral recumbency, the side of which is determined by the VS, with their dorsum on the edge of the table. With one hand placed on the patient's head, the neck should be flexed as far as able, keeping the nose slightly raised so that it is parallel to the table and in keeping with the sagittal midline of the patient (see Figure 3). This position must be maintained for the duration of the CSF tap; it is paramount that the patient is not moved whilst the spinal needle is inserted, as iatrogenic trauma

Figure 4. Positioning for a lumbosacral CSF sample, with the hind limbs pulled cranially.

Figure 5. The position for insertion of the spinal needle must be maintained while CSF is allowed to passively flow from the needle into the collection tubes; it is recommended that the assistant finds a position that is comfortable as insertion and collection can take some time.

to the spinal cord and/or cerebellum can occur. It is advised to ensure that you are comfortable maintaining the position for a period of time prior to the VS inserting the spinal needle, as it may take a few attempts for the surgeon to enter the cerebromedullary cistern.

The extreme flexed position of the patient's neck during a cisternal CSF tap can cause occlusion of the trachea and/or kinking of the endotracheal tube, compromising the airway. The patient's respiration rate and effort, alongside capnography and pulse oximetry if available, should be carefully monitored throughout the procedure. If respiratory compromise does occur then the VS must be alerted so that the procedure can be aborted and the spinal needle removed in order to straighten the patient's neck and re-open the airway.

Reinforced endotracheal tubes are available and can be useful for cisternal CSF taps due to their ability to avoid kinking. However, this is achieved via a spiral of metal in the tube, and as CSF collection is commonly performed following magnetic resonance imaging they are often not appropriate.

Lumbar CSF

A lumbosacral CSF sample, or lumbar puncture, is performed when a lesion or inflammatory process is suspected further down the spinal cord. Protein levels in CSF samples collected from a lumbar tap are typically twice those of a cisternal sample (Dewey & da Costa, 2015). It is performed at the L5/L6 intervertebral space in cats and smaller dogs or at the L4/L5 intervertebral space in larger dogs. Lumbosacral CSF collection is generally regarded as more difficult due to the smaller size of the subarachnoid space at this site.

The lumbar vertebrae should be palpated and counted to estimate the proposed needle insertion site, with a small square of fur clipped and aseptically prepared in the same manner as for a cisternal sample. Calculating the correct intervertebral space can be done either by counting the lumbar vertebrae back from the last rib (T13) or forward from the sacrum.

The patient is placed in lateral recumbency with the hind limbs extended cranially to open up the intervertebral space and allow for insertion of the spinal needle (Figures 4 and 5). In order to make palpation and identification of landmarks easier, the hind limbs should be extended and maintained in a midline position. Once again, a comfortable position should be found by the restraining assistant as the collection can often take several attempts. The patient must not be moved during the procedure to prevent iatrogenic trauma.

During lumbar CSF collection, the spinal needle will occasionally pass through the caudal spinal cord and/or cauda equina, producing a tail or leg twitch. This needle trauma should not cause any lasting damage, but can be alarming if not expected.

Post-CSF collection nursing care

Nursing care of the patient after CSF collection is generally focused on patient recovery from anaesthesia and observation of any additional neurological clinical signs. Heart rate, respiratory rate and temperature should be monitored until the patient is up, eating and normothermic.

Patients recovering from CSF collection are at risk of ICP changes; sometimes these may be seen immediately following collection by the nurse monitoring the anaesthetic, for example apnoea or bradycardia, but the patient must also be monitored closely on recovery for signs of increasing ICP and subsequent cerebellar/cerebral herniation. Cushing's reflex is described as an increase in systemic blood pressure with concurrent bradycardia and is commonly seen in patients as ICP increases (Fodstad, Kelly & Buchfelder, 2006). Systemic blood pressure increases in order to maintain cerebral blood flow, resulting in a reflex bradycardia. Unresponsive miosis with obtundation are seen when herniation occurs and the VS should be alerted immediately if the patient demonstrates these signs on recovery. An osmotic diuretic, for example mannitol (Mannitol, Terumo BCT Limited), should be kept nearby and can be administered under veterinary direction in these situations to rapidly decrease ICP and stabilise the patient.

Risks and contraindications

As with most diagnostic procedures there are risks involved in performing a CSF tap, which must be discussed with the client in order for them to provide informed consent. The risk of general anaesthesia may be a common discussion for many nurses, but additional risks can include CNS haemorrhage, ICP alterations leading to cerebral and/or cerebellar herniation and spinal cord trauma from incorrect needle insertion. These complications, while rare, can often be fatal. Airway complications, as previously mentioned, must also be taken into consideration.

Contraindications for CSF collection include: coagulopathies, suspected increased intracranial pressure or active CNS haemorrhage, vertebral fractures, dermatitis/infection over the proposed collection site, and patients unable to undergo general anaesthesia.

Conclusion

As an ultra-filtrate of blood plasma that provides nutrition and protection to the CNS, CSF plays an important role in the body. Its collection can provide valuable information on the health of the CNS and alongside advanced imaging can guide diagnoses and treatment for a range of neurological conditions. In knowing the anatomy, risks and correct handling required for collecting a CSF sample the veterinary nurse is well placed to assist the VS and complement the patient's care and recovery.

Disclosure statement

No potential conflict of interest was reported by the author.

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Multiple Choice Questions

1. **Which of the following are not a component of normal CSF?**
   - **(a)** Electrolytes
   - **(b)** White blood cells
   - **(c)** Red blood cells

2. **Which specialised group of cells produces CSF?**
   - **(a)** Arachnoid villi
   - **(b)** Pia Mater
   - **(c)** Choroid Plexuses
   - **(d)** Erythrocytes

3. **What is the primary clinical test performed on CSF after collection?**
   - **(a)** Cytology and protein
   - **(b)** Complete blood count
   - **(c)** Serum biochemistry
   - **(d)** Fluid analysis

4. **Which of the following drugs should not be given prior to a CSF tap?**
   - **(a)** Medetomidine
   - **(b)** Dexamethasone
   - **(c)** Buprenorphine

5. **What is the clinical term for an elevated white blood cell count in a CSF sample?**
   - **(a)** Pleocytosis
   - **(b)** Neutrophilia
   - **(c)** Lymphocytosis
   - **(d)** Anaemia

6. **How much CSF is it safe to collect from a patient?**
   - **(a)** 5ml
   - **(b)** 10ml
   - **(c)** 0.5ml per kg
   - **(d)** 1ml per 5kg

7. **Which collection site would be recommended for multifocal neurological disease?**
   - **(a)** Cerebromedullary cistern
   - **(b)** Lumbosacral articulation
   - **(c)** Both

8. **What is the drug of choice to administer when increased ICP is suspected?**
   - **(a)** Dexamethasone
   - **(b)** Fentanyl
   - **(c)** Mannitol
   - **(d)** Prednisolone

For the answers to the MCQs, please go to: **http://www.bvna.org.uk/publications/veterinary-nursing-journal**