Film: The spread of local anaesthetic solutions in the glass spine - Dr Len Carrie

Knowledge of the distribution of local anaesthetic solutions after injection into the subarachnoid space is derived largely from the development of clinical features such as analgesia, anaesthesia and motor block.

A visual and more accurate impression of the behaviour of these drugs can be achieved by the injection of coloured solutions of various baricities into a glass tube curved to simulate the vertebral column ("the glass spine") and filled with " mock" cerebrospinal fluid.

This film shows the use of such a glass spine to demonstrate the spread of spinal solutions both by single-shot injections in different patient positions and also through a spinal catheter.

Commentary to film

Introduction

A glass spine similar to that used in the film was first described in 1907 by Arthur Barker, Professor of Surgery at University College Hospital in London[1].

The glass spine used in this demonstration has been in the Nuffield Department of Anaesthetics since the early 1950's, when several photographs of it appeared in Professor R R Macintosh's famous monograph "Lumbar Puncture and Spinal Analgesia"[2]. It is a glass tube curved in the same way as the vertebral column and therefore the dural sac and subarachnoid space. There is a rubber injection port in the mid-lumbar region, and the cephalad end is sealed with a rubber bung into which is fitted an expansion chamber device. This is necessary because the glass spine (unlike the dural sac), being rigid is unable to expand to allow the injection of even a small volume of solution.

The glass spine is filled with normal saline, which has a density very similar to that of cerebrospinal fluid. Confusion has arisen because of the use of the term "specific gravity" in connection with cerebrospinal fluid and spinal solutions. Both density and specific gravity are affected by temperature, and it is better to use the term "baricity". This refers to the density of the solution compared with that of cerebrospinal fluid at body temperature. "Hyperbaric" refers to solutions with density greater than that of cerebrospinal fluid at body temperature, "isobaric" refers to solutions with a density the same as that of cerebrospinal fluid and "hypobaric" to solutions with a density less than that of cerebrospinal fluid.

Hyperbaric solution injected with the patient in the lateral position and then placed supine

The first part of the demonstration shows the injection of a hyperbaric solution dyed pink with waxoline rhodamine in the lateral horizontal position and the glass spine then turned immediately supine. The demonstration shows how the injection in the mid-lumbar region would spread across and block the nerve roots of the cauda equina and then, after turning the patient into the supine position how the hyperbaric solution runs both caudad and cephalad in the subarachnoid space. Spread to the most dependent part of the thoracic cavity occurs remarkably quickly, but spread higher is prevented by the uphill gradient of the spine from this point. The demonstration also shows how steeply head-down the patient would have to be placed for the solution to spread dangerously high, and on the other hand how easily it can spread high if the patient is left in the lateral but head-down position.

Hyperbaric solution injected with patient in sitting position

If the injection is made slowly enough in this position the hyperbaric solution trickles down to affect only the lowest sacral segments - the so-called “saddle-block”. More commonly the solution is injected quickly enough to spread across and produce anaesthesia in the whole cauda equina, but if the patient is left in the upright position, the effect is limited to the lower lumbar and sacral nerve roots.

Hyperbaric solution injected with patient in sitting position then placed supine

The sitting position is quite popular for injection of hyperbaric solutions even when surgery is to be quite extensive eg for Caesarean section. The demonstration shows the dye cutting across the region of the cauda equina as usual and then when the horizontal position is assumed, the dye runs in both directions - caudad and cephalad in the subarachnoid space. As with injection of hyperbaric solution in the recumbent position, the local anaesthetic solution usually reaches the mid-thoracic region, but as an unpredictable amount of the solution is trapped in the caudal end of the dural sac, there is less available for spread cephalad. This may result in a shorter duration of action in the upper affected segments.

Isobaric solution injected with patient in lateral position then placed supine

The isobaric solution used for this part of the demonstration is dyed with methylene blue. Injection in the lateral, recumbent position shows the dye once again cutting across the region of the cauda equina. However, when the supine position is adopted, the dye makes no attempt to move upwards or downwards in the subarachnoid space, producing a more localised block than the hyperbaric solution. Clinically, this means that this type of block is excellent for operations on the lower limb and abdomen, but higher spread is unpredictable. This is because these solutions, being unaffected by gravity are unpredictably affected by factors over which there is less control, for example temperature. Most plain local anaesthetic solutions are approximately isobaric, but while slightly hyperbaric at room temperature, may be marginally hypobaric when warmed to body temperature. If the patient is put in the head-up position, these solutions may rise to produce high levels of analgesia. Other factors affecting these isobaric solutions include “internal barbotage” as the nerve roots produce a stirring-up effect in the subarachnoid space, and certainly in pregnant patients aorto-caval occlusion causes congestion of the epidural veins and a squeezing effect on the dural sac, causing the block to spread higher. Other unpredictable factors include coughing or straining and because of these factors these solutions can sometimes spread unexpectedly and disconcertingly high.

The demonstration then shows the effect of barbotage in extending the extent of spinal anaesthesia, a technique of more relevance in former years when large bore needles were used for spinal anaesthesia.

Solutions injected through a spinal catheter with patient supine

This part of the demonstration shows a problem which may arise when continuous spinal anaesthesia is attempted via a catheter in the subarachnoid space.

The background to this part of the demonstration is set in the late 1980’s and early 1990’s when there was increased interest in the use of continuous spinal anaesthesia. In order to reduce the incidence of postdural puncture headache resulting from the size of needle required to introduce these spinal catheters, several manufacturers produced fine gauge spinal catheters, mostly 28 gauge which would pass through a 22 or 23 gauge needle, but also a 32 gauge “microspinal” catheter which would pass through a 26 gauge needle. Unfortunately, before these catheters had been in use for long, several cases of cauda equina syndrome were reported to the Food and Drug Administration in the United States, who consequently in May 1992 withdrew all catheters smaller than 27 gauge from the US market.

During continuous spinal anaesthesia it was common to place the patients in the supine position before injection. Whether catheters pass cephalad or caudad after introduction into the subarachnoid space is unpredictable, and the demonstration shows what may happen if the catheter passes caudad. The demonstration, in this case using a 28 gauge catheter, shows how the hyperbaric solution is directed towards the caudad end of the dural sac, where a very high concentrations of dye builds up before it eventually spills over the apex of the lumbar convexity to begin to affect higher nerve roots. It was these very high concentrations of local anaesthetic which were believed to be neurotoxic and responsible for the cauda equina lesions.

The final part of the demonstration shows the effect of injection of an isobaric (blue) solution through a caudad facing catheter. In this case, although the dye is directed towards the caudal end of the dural sac, the lack of a gravitational effect prevents the accumulation of a very high concentration of dye in the region which would be occupied by the lowest sacral nerve roots. This indicates that isobaric solutions are safer for continuous spinal anaesthesia.

Summary

Although it is now almost 100 years since the first description of the glass spine, it remains a uniquely visual method of demonstrating the spread of spinal solutions injected into the subarachnoid space.

References

1. Barker AE. Report on clinical experiences with spinal analgesia in 100 cases, and some reflections on the procedure. British Medical Journal 1907; i: 665-674.

2. Macintosh RR. Lumbar Puncture and Spinal Analgesia, 1st Edn. Edinburgh, E&S Livingstone, 1951.

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