Welcome to another talk in André Boezaart’s “Must-know anatomy for regional anesthesia and acute pain medicine” lecture series. This lecture is a brief outline of the *microanatomy of the epidural space*, attempting to address the questions: why are epidural blocks segmental, and why don’t older people suffer postdural puncture headache as frequently as younger people do?
The author is André Boezaart, a Professor of Anesthesiology and Orthopaedic surgery at the University of Florida College of Medicine.
This talk is based on a paper by Shantha and Evans. Although it is a relatively old publication, it should be viewed as a milestone paper and you are strongly encouraged to study this article in its entirety. The factual information of this article has not been disputed since its publication and it is largely beyond debate. It convincingly explains why epidural blocks are segmental and why postdural puncture headache is more prevalent in younger patients than in older people.
First, we must understand the microanatomy of the arachnoid villi that are present in all humans in the spinal roots and other places such as the sagittal sinus. The paravertebral spinal root arachnoid villi demand our attention for this talk.

Please study this drawing of Mary Bryson, which she did for the textbook, “The Anatomical Principles of Regional Anesthesia and Acute Pain Medicine” by the author of this talk.
There are five types of arachnoid villi. Type one villi, number 8 in this drawing, are simple arachnoid proliferations consisting of several layers of arachnoid epithelial cells and found along the root arachnoid. They are consistently found where the pia (#3) and arachnoid (#5) come together at number 16 to obliterate the subarachnoid space. These proliferations come in many shapes and sizes and may protrude into adjacent subdural spaces (#6).
Type two arachnoid villi, number 9, can be seen partially protruding into the dural sheath, number 7, without breaching the dural continuity, at the same time reducing the thickness of the dura at the site.
Type three villi, number 10, completely breach the dura (#7), but do not protrude beyond it.
Type four arachnoid villi, marked number 11, protrude out of the dura into the epidural space, …
… and type five villi protrude beyond the dura in proximity to epidural veins and partially protrude into the veins. This is the same as is commonly observed in the sagittal sinus. Types one through three villi are commonly found, especially in young people, whereas types four and five are less frequent, but their numbers increase with advancing age.

To block the sodium channels of the nerve axons, the local anesthetic must diffuse to the axons.
Structurally, the dura is composed of thick collagen bundles mixed with elastic fibers and fibroblasts that run obliquely and longitudinally. The dura also contains an abundant amount of polysaccharides. The thickness of the dura is greatest cephalad and is thinner in a caudad direction. The nerve root dura is also thin compared to the spinal dura and becomes progressively thinner toward the intervertebral foramen; it continues as perineural connective tissue of peripheral nerves, the perineurium (black arrows below)
The spinal dura is relatively impermeable to local anesthetics. Studies have shown only very little radioactive lidocaine in the spinal dura itself.
The arachnoid mater is a membrane that covers the brain, the spinal cord, and the dorsal and ventral nerve roots and is situated between the dura and the pia mater (below).
The arachnoid mater consists of several layers of flat squamous cells laid one on top of the other with potential spaces, the so-called interarachnoid spaces (blue arrows above), between the layers and a delicate network of collagen, elastic fibers, and blood vessels within. The arachnoid covering the spinal roots has an important and remarkable histological feature.

Proliferations of arachnoid cells lining villus structures have been consistently demonstrated in dogs, humans, primates, and rats. In humans and primates, arachnoid proliferations and villi have been demonstrated along both the dorsal and ventral roots.
The arrow in this photograph illustrates the acquired subarachnoid (extra-arachnoid space. It is possible to place epidural catheters into this space, which results in the so-called “massive epidural”, a patchy epidural block with spread out of proportion to the amount of drug injected, with a late onset, and massive sympathectomy.
There is no anatomic difference between the arachnoid villus structures of the spinal root, the sagittal sinus, or the optic nerve.
The endothelial lining of the arachnoid villi is a mosaic of lipid and pores, the latter occupying a larger part of the surface than in the blood-cerebrospinal fluid (CSF) barrier. Lipid-soluble substances can penetrate both lipids and pores, whereas water-soluble substances can escape and pass through the pores.
In young patients, epidural injections extend through the neural foramina around the spinal nerve roots (#15, indicated with the arrow above), and can more readily penetrate the thinner dura around the spinal roots inside the spinal canal than the thicker dura surrounding the spinal cord itself, which explains the segmental nature of epidural anesthesia.

The drug is effective if it reaches the subarachnoid space (#4) because …
… the pia mater (#3, and electron-microscopy picture below) offers almost no resistance to diffusion because of its natural fenestrations. If the drug diffused through the relatively thick spinal dura, which local anesthetic agents do not, the effect of the local anesthetic would occur on the spinal cord, similar to a subarachnoid block – non-segmental and blocking everything distal to the injection site.
In the older arteriosclerotic patient, however, there is lack of paravertebral spread, but because of the increase in number and size of spinal nerve root inside and outside the spinal canal arachnoid villi as shown on this MRI, and the further penetration of the villi into the spinal root dura, a further decrease in the thickness of the spinal root dura occurs, increasing the area of permeability and penetration into the spinal root.
A lack of paravertebral escape with the increased permeability area in the aged is most likely responsible for the faster onset and higher dermatomal levels of analgesia, even with smaller doses of local anesthetic. With little to no leakage into the paravertebral space through the intervertebral foramen, the result is a sharper rise in pressure and concentration in the epidural space, which facilitates increased penetration of the local anesthetic agent into the root subarachnoid space.
The phenomenon of decreased leakage of CSF into the paravertebral space is the most likely reason why the development of headache after lumbar puncture in the elderly compared to the younger is rare. In the aged, the leakage of CSF, thought to be at least partially responsible for postdural puncture headache, continues to leak into the epidural space but cannot escape into the paravertebral space. This builds up enough pressure to cause partial or complete blockage of further CSF leakage. In young patients, CSF continues to escape from the subarachnoid space to the epidural space and to the paravertebral spaces. The result is low subarachnoid CSF pressure and its sequelae (spinal headache), dramatically relieved by pressure-equalizing measures such as epidural blood patch.
Thank you for your attention and we look forward to seeing you again soon in another talk by André Boezaart in this series on the minimum anatomical knowledge a practitioner should attain for regional anesthesia and acute pain medicine procedures.
REFERENCES


This lecture series was adapted from:

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