A NEW INTERPRETATION OF THE ORIGIN OF EXTRADURAL SPACE NEGATIVE PRESSURE

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SUMMARY

The negative pressure in the extradural space is the result of the interaction of hydrostatic forces created between the vertebral canal (a stiff-walled cylinder) and the dura mater, with its content of cerebro-spinal fluid (CSF), which behaves as a cylinder that can collapse according to the position of the subject. In order to corroborate this hypothesis, we have designed a model formed by a sealed, water-filled, glass cylinder ("vertebral canal"). In the interior there is a collapsible, non-distendible, water-filled cylinder ("dural sac"), in free communication with a reservoir which represents the CSF contained in the cranial cavity. Changes in the position of the model produce subatmospheric pressure in the space between both cylinders ("extradural space"), as happens in man.

The existence of a subatmospheric pressure in the extradural space was first described by Jansen (1926). Most theories that try to explain this phenomenon, consider one of the following mechanisms:

(a) Negative pressure is an artefact produced by the displacement of the dura mater by the extradural needle (Jansen, 1926; Giordanengo, 1934; Eaton, 1939; Bromage, 1953).
(b) Negative pressure results from a disproportion between the growth of the vertebral canal and that of the spinal cord and its sheaths, or by the changes in volume of the vertebral canal during flexion of the spine (Reid and Sherrington, 1890; Heldt and Moloney, 1928; Dogliotti, 1933).
(c) Negative pressure is produced by changes in volume of the extradural venous plexus (Bonniot, 1934).
(d) Negative pressure is negative from intrathoracic pressure transmitted through the intervertebral foramina (Macintosh and Mushin, 1947; Bryce Smith, 1950; Macintosh, 1950).

None of the aforementioned hypotheses gives a satisfactory explanation of the extradural negative pressure in all clinical or experimental situations.

The vertebral canal may be considered as a hollow tube with stiff walls, the pressure relationship of which with the extradural space and other levels of the extradural space is limited by the presence of different anatomical structures, as has been demonstrated by Usubiaga, Moya and Usubiaga (1967). They demonstrated that the administration of 10 ml of an anaesthetic solution at any one level of the extradural space, did not produce modifications in the negative pressure of the other portions of the space.

The dural sac is enclosed within this stiff chamber, being strongly fixed to the occipital foramen, and behaving as a non-elastic cylinder, which can collapse easily (Shanta and Evans, 1972; Peters, Palay and Webster, 1976; Bromage, 1978). Therefore, the extradural space is limited to the vertebral canal, while the subarachnoid space is in free communication with the intracranial cavity, the content of which has a small degree of compliance. These structural characteristics determine a series of hydrostatic phenomena, which I have analysed.

DESCRIPTION AND PREPARATION OF THE MODEL

The experimental model (fig. 1), consisted of a sealed, water-filled cylinder, "vertebral canal" (VC), and a collapsible non-elastic, water-filled polyethylene cylinder, "dural sac" (DS), contained in the interior of the glass cylinder. Its lower end was connected to a Hewlett-Packard 1280 strain-gauge transducer (SAT), which measured the "subarachnoid pressure".

A second pressure transducer (ET) was connected to the space between the polyethylene tube and the glass cylinder, "extradural space", and measured the pressure in this space. At its upper end, the "dural sac" was connected to a reservoir...
Fig. 1. The experimental model. CC = Reservoir; SO = side opening; ET = "extradural" transducer; VC = glass cylinder ("vertebral canal"); DS = polyethylene cylinder ("dural sac"); SAT = "subarachnoid" transducer.

(CC) that represented the CSF content of the cranial cavity.

To prepare the empty model for determinations, the system was positioned in the horizontal plane (fig. 2 (HP)), and both cylinders were filled with water, until a positive pressure of 7 mm Hg built up in the "dural sac", which was approximately the pressure of the subarachnoid space.

This pressure was registered by the lower transducer (SAT). Then the model was righted to a vertical position (fig. 2 (VP)). Because of the redistribution of fluid within the "dural sac", the latter was now completely filled, thus a positive pressure was created in the space between both cylinders. Then, an amount of water from this space was removed via the connector of the extradural transducer (ET), until the "extradural pressure" reached a value of zero. The model was then ready.

Fig. 2. Preparing the experiment. Step one: The model described in figure 1 was placed in a horizontal position (HP). After filling the "dural sac", "subarachnoid" pressure was registered in tracing C (right hand). The registered pressure corresponded to 7 mm Hg. Step two: The model was placed in the vertical position (VP). "Subarachnoid" pressure had increased to 35 mm Hg because of the weight of the fluid column that it contained, and was registered in tracing B. The pressure that corresponded to the "extradural" space was registered in tracing A. Some of the water of this space was removed via the connector with "extradural" transducer (ET), until the "extradural pressure" reached an approximate value of 0 mm Hg.
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FIG. 3. Carrying out the trial. The simultaneous decrease in "subarachnoid" pressure (tracing B), and that of the "extradural" pressure (tracing A), can be demonstrated by taking the model from the vertical position (VP) to the horizontal position (HP). The "subarachnoid" pressure decreased from 40 mm Hg to a value of 6 mm Hg, and the "extradural" pressure, decreased from 0 mm Hg to a value of -20 mm Hg. This decrease in pressure was progressive and was augmented when the tilting of the model was greater.

RESULTS
As we changed the position of the model from the vertical to the horizontal plane (fig. 3 from (VP) to (HP)), we observed that the positive pressure within the "dural sac" registered by the lower transducer (SAT), as shown in tracing B, began to decrease, and the pressure of the "extradural space", registered by the upper transducer (ET), as demonstrated in tracing A, became negative and increased in negativity as the tilting of the model increased. Because of the negative pressure in the "extradural space", there was no passage of water to the reservoir from the dural sac.

DISCUSSION
In upright man, the CSF will exert a positive hydrostatic pressure on the walls of the dural sac, which will, in turn, have only a limited influence on the pressure of the extradural space because of its non-elastic nature. If the subject gradually adopts a supine position, there will be a progressive decrease of the hydrostatic pressure of the CSF, as the height of the liquid column is reduced (Shah, 1981). As a consequence, the previously taut parts of the dural sac are liable to collapse, while the vertebral canal, being a stiff cylinder sealed by anatomic structures, cannot follow the eventual changes of the dural sac. The redistribution of CSF in the subarachnoid space creates a negative pressure between the dura mater and the vertebral canal during the recumbent position. This negative pressure compensates any displacement of CSF to the cranial cavity.

In summary, any decrease in hydrostatic pressure of the CSF in the vertebral subarachnoid space will modify the shape of the dural sac because of CSF redistribution, and this will be reflected as negative pressure changes in the extradural space, because of the stiffness of the vertebral canal. Thus, the greater the departure from the vertical position of the patient, the greater the negative values of that pressure (Bonniot, 1934; Shah, 1981).
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REFERENCES


NOUVELLE INTERPRETATION DE L'ORIGINE DE LA PRESSION NEGATIVE DANS L'ESPACE PERIDURAL

RESUME

La pression negative dans l'espace peridural est la resultante de l'interaction de forces hydrostatisques crees entre le canal vertebral (un cylindre a parois rigides) et la dure-mere, avec son contenu en liquide cerebrospinal (LCR), qui se comporte comme un cylindre pouvant se collaber selon la position du sujet. Pour verifier cette hypothese, nous avons conçu un modele formé par un cylindre de verre clos, rempli d'eau ('canal vertebrale'). A l'interieur, il y a un cylindre collabable, non distensible, plein d'eau ('sac dural'), en communication libre avec un reservoir qui represente le LCR contenu dans la cavite cranienne. Les changements de position du modele entraînent une pression inferieure a la pression atmospherique dans l'espace compris entre les deux cylindres ('espace peridural'), comme cela existe chez l'homme.

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EINE NEUE INTERPRETATION ÜBER DIE HERKUNFT DES NEGATIVEN DRUCKES IM EXTRADURALRAUM

ZUSAMMENFASSUNG

Der negative Druck im Extraduralraum ist das Ergebnis des Zusammenspiels von hydrostatischen Kräften, die zwischen dem Rückenmarkskanal (einem steifwandigen Zylinder) und der Dura Mater mit der in ihr enthaltenen Zerebrospinalflüssigkeit (CSF) besteht, die sich wie ein Zylinder verhält, der je nach Lage des Lebewesens kollabieren kann. Um diese Hypothese zu untermauern, haben wir ein Modell entworfen, das aus einem verschlossenen, mit Wasser gefülltem Glaszylinder ('Rückenmarkskanal') besteht. Im Inneren befindet sich ein kollabierfähiger, aber nicht-dehnbarer wassergefüllter Zylinder ('Dural sack'), der in freier Verbindung mit einem Vorratsbehälter steht, der die CSF darstellt, die im Schädel enthalten ist. Veränderungen der Lage des Modells rufen subatmosphärische Drücke im Raum zwischen beiden Zylindern ('Extraduralraum') hervor, wie es ebenso beim Menschen geschicht.

UNA NUEVA INTERPRETACIÓN DEL ORIGEN DE LA PRESIÓN NEGATIVA DEL ESPACIO EXTRADURAL

SUMARIO

La presión negativa en el espacio extradural resulta de la interacción de fuerzas hidrostáticas creadas entre el canal vertebral (un cilindro con paredes rígidas) y la duramáter, con su contenido de fluido cerebro-espinal (CSF) que actúa como un cilindro que puede desplomarse según la postura del sujeto. Con el objeto de corroborar dicha hipótesis, hemos diseñado un modelo conformado por un cilindro de vidrio hermético, llenado con agua (el "canal vertebral"). En el interior, hay un cilindro lleno de agua desplomable y no-distensible (el "saco dural"), en comunicación libre con un depósito, que representa el CSF contenido en la cavidad craneal. Los cambios de postura del modelo producen una presión sub-atmosférica en el espacio situado entre ambos cilindros ("espacio extradural"), lo mismo que ocurre en el ser humano.