Construction of a Human Spinal Canal Model

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A transparent model of the human spinal canal and its partial contents was constructed to aid in the study of intrathecal agents used for anesthesia. General specifications included: (1) transparency of its parts, (2) anatomic approximation, (3) thermal control of the canal, (4) multiple fluid-tight access sites to the canal, (5) three-plane position potential, (6) complete disassemblability for cleaning and for part replacement. The model's components can be divided into four categories: the external thermal jacket, the curved spinal canal, the spinal cord and its nerve roots, and the simulated cerebrospinal fluid. It was held in a metal support capable of infinite planar adjustments. Figure 1 displays the disassembled parts.

The Thermal Jacket and Mounting

The thermal jacket, representing the patient's body, supported the spinal canal and was, in turn, secured by a metal support capable of easy adjustment in three planes. As shown in figure 2, the full assembly was mounted on a portable stand with a Powers water thermostatic control unit. The jacket support was constructed of 3/8 inch diameter stainless steel, strong enough to hold the water loaded functioning system. The parts of the jacket support are shown in group A of figure 1.

Temperature of water flowing from hot and cold taps was regulated in the Powers unit. The thermal jacket (group B of figure 1), received the water through its ingress port. Its body was 75 cm. long and was constructed of 3/4 inch wall, 4.5 inches inside diameter plexiglass tubing. Conventional threads were turned on both ends. The end screw-caps were machined from solid plexiglass blocks and grooves were cut into them to receive 0 rings that seated against the polished ends of the body. The center of the upper end cap was further refined with a double 0 ring assembly to receive the upper end of the canal. This type of assembly supported the upper end of the canal and allowed both linear and rotational adjustment of the canal.

Spinal needle access through the body was obtained by drilling holes at desired areas, cementing fitted picettes to them with X-112R acrylic cement and covering their ends with multiple-puncture rubber nipples. The ingress and egress ports for the thermal water were drilled at the inferior and superior ends of the body in a different plane than the spinal-needle access plane to eliminate hose interference during use.

The Canal

In this model the canal functioned as the subarachnoid space and was constructed of a 66 cm. length of 3/8 inch wall, 3/8 inch inside diameter plexiglass tubing. This was heated

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Fig. 1. Component parts of spinal canal model. A—assembly holder, B—thermal jacket, C—canal, D—cord and nerve roots.
aperture of the previously-mentioned end cap. This portion was protected from becoming out of round by a fitted sleeve which was temporarily placed around it during heating and bending. Following cooling at room temperature, spinal needle access ports were marked off at desired spots and these corresponded to the ones on the thermal body. Holes were drilled, small pipettes cemented in place and rubber nipples attached in the same manner as was done with the jacket.

A four pronged spider was attached to the canal at the lumbar area to support the column against lateral pressure applied during spinal puncture, since the only other support was at the superior end. During assembly the canal with its attached spider was introduced through the inferior end of the jacket, into the double 0 ring aperture of the superior end cap. The spinal needle access ports of the canal and jacket were aligned and the 0 ring tightened.

The inferior end of the canal was covered with a rubber fitting allowing needle access. The fitting on the superior end had a 5-mL syringe attached which acted as a variable reservoir. The freely movable plunger on the syringe allowed fluid to be injected into or removed from the filled canal without causing pressure changes. It also facilitated maintenance of a closed system so the model could be operated in the horizontal plane.

The Cord

A 52 cm. length of 3/4 inch teflon rod was used for the cord and its elastic qualities allowed conformity to the canal’s curvatures. It terminated at an area corresponding to L2 on the jacket. One mm. diameter, teflon coated, copper pacemaker wire was used to represent the 26 pairs of emerging anterior and posterior nerve roots. Holes were drilled through the cord at the site of their emergence and the wires were pushed through. The length of the wires representing the nerves was determined by the area of their emergence through the arachnoid-dura. At this point the anterior and posterior roots of each side were soldered together. Different color wires were used for cervical, thoracic, lumbar, sacral and coccygeal nerves visually to empha-
size their relationships. The assembled spinal cord and nerves were introduced through the inferior end of the canal, which represented the subarachnoid space, and pulled up to the desired height. Because of the grass-skirt effect of the trailing nerves and cauda equina, the assembly was removed by pulling it through the superior end of the canal.

**Simulated Cerebrospinal Fluid**

The basic formula for simulated cerebrospinal fluid was calculated from information from Bodansky’s text book. The materials used to make 1,000 cc. of fluid were: NaCl 7.250 g., KCl 0.259 g., CaCl₂ 0.144 g., MgCl₂·6H₂O 0.231 g., Na₂HPO₄ 0.060 g., urea 0.130 g., glucose 0.610 g., NaHCO₃ 2.250 g., and human albumin 1.25 ml. Except for albumin, this agrees well with that used by Mitchell et al. in his preparation of simulated fluid. It required approximately 0.125 ml. of 85 per cent lactic acid to lower the pH to 7.3. To prevent precipitants, each of the materials was put into separate solution before being added to the mixture. NaHCO₃ was added last and, as soon as sufficient water was added to make up the 1,000 cc. required, oil was layered on top. To prevent escape of CO₂ and pH changes. This fluid compared favorably with cerebrospinal fluid and had an osmolality of 297, a specific gravity of 1.0050, and a pH of 7.30 at 37°. The canal was charged with this fluid from its upper end.

**USE OF MODEL**

This model was used for osmolality, density, refraction, and pH studies of various concentrations and combinations of intrathecal anesthetic agents. Through the multiple access sites, simultaneous sampling could be done and telethermometry facilitated. By coloring the solutions with a drop of methylene blue it was also used to demonstrate to students the movement of injected intrathecal agents. After injection in the vertical (sitting) position, the model could easily be put into the horizontal (lying) position, prone, supine, or Trendelenburg. The effects of positioning, rate of injection, baricity, or other controllable variables to the spread of the injected solution could be visibly shown. An unanticipated dividend of filling the canal and body with water was the optical magnification of the size of the cord. The model was easy to maintain and clean; the most used puncture-site nipples were inexpensive and easily replaced.

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**REFERENCES**


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**Functional Reduction of Anatomical Dead Space in the Management of Acute Alveolar Hypoventilation**

**E. Stresemann, M.D.*

Treatment of acute alveolar hypoventilation with intermittent positive pressure breathing (IPPB) will be ineffective, even on high inspiratory oxygen concentrations, if it does not increase tidal volume and thereby prevent CO₂-retention. If, for example, tidal volume is 250 ml., there will remain, after subtracting 150 ml. of dead space volume, 100 ml. for alveolar ventilation. Given a CO₂ concentration of 5.6 per cent in the alveolar air, a CO₂ output of 200 ml./minute, and a respiratory rate of 20, at each expiration 10 ml. CO₂ are

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