A comparative study of epidural and cisternal pressure in dogs

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The epidural and cisternal pressure was recorded simultaneously in eight dogs. Epidural pressure was monitored with a Ladd fiberoptic sensor, and the cisternal pressure via a Statham transducer and a Grass polygraph. Various pressure levels were compared when mock cerebrospinal fluid was injected into the cisterna magna. The results were analyzed statistically and, within a range of 0 to 70 mm Hg, a high degree of correlation was found between the pressures of the two compartments ($r = 0.96$ to $1.0$).

Key words: intracranial pressure, comparative study

One of the least invasive and most trouble-free techniques for intracranial pressure (ICP) monitoring is the epidural fiberoptic pressure sensing method. The accuracy of epidural pressure recording, however, has been questioned for some years. Coe, et al., have suggested that transducers placed in the epidural space are subjected to a continuous wedge pressure, and that the reading would be higher than the intradural pressure.

Sundbärg and Nornes, using a miniature epidural transducer in a study of seven patients and a dog, found that there was a linear correlation between simultaneous recordings of the epidural and ventricular fluid pressure. Epidural pressure was consistently higher than ventricular fluid pressure and the difference in pressure increased at higher readings. Corones, et al., using a small perforated metal capsule for epidural recording, reported excellent correlation between the epidural and cerebrospinal fluid (CSF) pressure in dogs, but the epidural pressure was considerably higher than ventricular fluid pressure in patients in low pressure ranges, while the opposite was true at high pressure levels. Jørgensen and Riishede, using the same method as Sundbärg and Nornes, recorded epidural and ventricular fluid pressure in 20 patients. They concluded that the epidural pressure was 5 to 10 mm Hg higher than the ventricular fluid pressure, and noted that the difference in readings increased slightly at higher pressures. Turner, et al., found good linear correlation between epidural and ventricular fluid pressure, with a tendency for divergence between the two pressures at high values. Zierski, using the Philips epidural transducer, could not confirm this tendency.

Since only one comparative study is known to have used the epidural fiberoptic method, we wished to judge the accuracy of the Ladd fiberoptic system. We have compared epidural and cisternal fluid pressure in dogs, and the analysis of our findings is the subject of this report.

Materials and Methods

Following preliminary standardization of the technique, a series of experiments were performed on eight dogs weighing 13.4 to 23 kg. The dogs were anesthetized with intravenous Nembutal (pentobarbital, 30 mg/kg), intubated, and ventilated with a volume-controlled Boyle respirator. To provide stable conditions for the pressure measurements, the dogs were immobilized with intravenous gallamine. Anesthesia was maintained with a gaseous mixture consisting of oxygen, nitrous oxide, and methoxyflurane. Electrocardiographic and rectal temperature monitoring were continuous throughout the procedure.

Epidural pressure monitoring was recorded contin-

* Philips epidural transducer manufactured by Philips Co., Medical Division, Endthoven, The Netherlands.
† Boyle anesthetic machine is no longer manufactured.
Dura Sensor Burr Hole

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FIG. 1. Schematic drawing of the experimental set-up.

Dura Sensor Burr Hole

Ladd ICP Monitor

Omniscribe Recorder

Grass Polygraph Recorder

Statham Transducer

Harvard Infusion Pump

Respirator

FIG. 1. Schematic drawing of the experimental set-up.

continuously for up to 5 hours with a Ladd fiberoptic epidural sensor implanted in the epidural space through a small craniectomy in the left parietal bone. Wedge effect was eliminated by stripping the dura from the inner table over a wide area prior to the insertion of the sensor. The epidural pressure was continuously recorded on a variable-speed Omniscribe recorder throughout the experiment. The cisternal fluid pressure was measured from a short No. 20 disposable lumbar puncture needle inserted into the cisterna magna at the atlanto-occipital junction. The cisternal pressure was recorded through a Statham 23D transducer (calibrated from 0 to 100 mm Hg) on a Grass polygraph. The midline spine was used as the zero reference point for positioning the transducer. Blood from a femoral arterial line was collected at the beginning and end of each experiment for the analysis of blood gases.

In order to initiate a pressure response, mock CSF loading of the cisterna magna was carried out via a three-way stopcock with 1 ml of physiological saline injected from a syringe (Fig. 1). In the first four dogs, the injection was made by hand within 10 seconds. During the injection, the Statham transducer was blocked from the cisternal needle and only the pressure regression phase was recorded. In the remaining four dogs, the injection of physiological saline was made by a precalibrated Harvard infusion pump. The mock CSF was infused with the transducer open to the cisternal needle via the three-way stopcock, and continuous recording was obtained on the Grass polygraph, both during the injection phase and the pressure regression phase (Fig. 2). Infusion with the Harvard pump was made at a rate of 4.12 ml/min in Dogs 5, 6, and 7, and infusion rates of 1.03 ml/min and 1.94 ml/min were used in Dog 8.

The mock CSF infusion was repeated in sequence with 1 ml physiological saline at intervals of 5 minutes, and eight injections were made for each series. The time interval of 5 minutes was chosen between consecutive injections because we found in previous experiments that pressure equilibrium was established approximately 5 minutes after each injection. In the last dog, a pressure correlation study was also made when a large volume (16 ml) of normal saline was infused at a rate of 1.94 ml/min (Fig. 3).

Data were analyzed by plotting the cisternal against the epidural pressure at corresponding time intervals from the simultaneous pressure tracings. The relationship between the epidural and cisternal pressures was established statistically by the least-squares method using the respective regression lines, their slopes, and their intercepts, and calculating the coefficient $r$, which characterizes the strength of the correlation between the cisternal and epidural pressures. A value close to 1 indicates a high degree of correlation between the two pressures.

Results

The first injection into the cisterna magna (using 1 ml of physiological saline) makes a minimal change, if any, in the ICP. Following the second injection, the ICP begins to rise, and by the third or fourth injection, the peak pressure and the decay time stabilize in a reproducible and constant manner. The pressure decay is exponential, with a rapid initial decline followed by a more gradual decrease to near equilibrium in

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§ Ladd fiberoptic epidural sensor manufactured by Ladd Research Industries, Inc., P.O. Box 1005, Burlington, Vermont.

§ Statham 23D transducer manufactured by Statham Instruments, Inc., 2230 Statham Boulevard, Oxnard, California, and Grass polygraph manufactured by Grass Instrument Co., 101 Old Colony Avenue, Quincy, Massachusetts.

∥ Harvard infusion pump manufactured by Harvard Apparatus Co., 150 Dover Road, Millis, Massachusetts.
Epidural and cisternal pressure in dogs

![Graph showing simultaneous recordings of pressure rise and decay](image)

**Fig. 2.** Simultaneous recordings of pressure rise and decay on the Omniscribe recorder and on the Grass polygraph.

About 5 minutes from the peak of the curve. This pressure decay is almost a mirror image of the pressure-volume response described by Langfitt, et al.

After injecting 1 cc of fluid at a rapid rate of infusion (4.12 ml/min), there was a lag of the pressure rise in the epidural space and the epidural pressure continued to rise for a few seconds after the cisternal pressure had peaked. After reaching the peak epidural pressure, there was excellent correlation between the epidural and the cisternal pressures as expressed by the scattergrams and regression lines (Figs. 4 and 5).

With a slower rate of infusion (1.03 ml/min), the time lag between the epidural and cisternal pressure peak was not noted.

The slopes of the regression lines lie between 0.82 and 1.18, and the intercept between 0.1 and 7.2, indicating a high degree of correlation between the epidural and cisternal pressures, the latter being slightly below the epidural pressure, except in Dog 2 where the cisternal pressure tended to read higher than the epidural pressure. Epidural and cisternal pressures were nearly equal at baseline pressures; however, the difference increased at higher pressure readings. The greatest difference was not more than 14 mm Hg, and the average difference obtained at higher readings was not more than 10 mm Hg.

**Discussion**

Our study, which compares epidural with cisternal fluid pressure in dogs, has shown that the Ladd epi-
dural sensor is both accurate and reliable within the pressure range 0 to 70 mm Hg. The epidural pressure was generally higher than the cisternal pressure, with the exception of Dog 2 where the contrary was true. We have no explanation for this single exception. We have found that the pressure difference between the epidural and cisternal readings increases slightly at higher pressures. These findings are in agreement with those of Sundbärg and Nornes, Jørgensen and Riishede, Coroneos, et al., and Turner, et al.

In clinical monitoring, Zierski has found that, in half of his cases, the pressure difference exceeded 5 or 10 mm Hg, while the correlation in pressure changes at different sites was good. He suggested that the condition of the dura at the site of recording is the most important contributing factor to epidural overreading. He maintained, nevertheless, that the epidural pressure device is a reliable method for monitoring the trend of ICP changes. Esparza, et al., in their study of epidural and ventricular fluid pressure measurements during the progression of supratentorial expanding lesions suggested that brain displacement is able to induce differences between these two pressures by blocking CSF circulation. Not ruling out that methodological factors may play a part in the pressure differences, they believed that the pressure gradients observed in their study were genuine. In agreement with Esparza, et al., we think that the pressure differences are genuine and reflect physiological differences in the various intracranial compartments.

An interesting finding in our study is the time lag in the epidural pressure response during the infusion phase. At a higher rate of infusion, the cisternal pressure peaked first, followed by the epidural pressure which continued to rise to a peak after the infusion had stopped. This time lag in the pressure response disappears at a slower rate of infusion. Our assumption is that this phenomenon is partly due to the elastic properties of the dura but also is related to the inertia of the Ladd monitor (20 mm Hg/sec). The results of simultaneous cisternal and epidural pressure monitoring using the Ladd fiberoptic epidural sensor suggest that the Ladd system is both accurate and reliable at a pressure range of 0 to 70 mm Hg, with a correlation coefficient between 0.96 to 1.0, indicating a high degree of correlation between cisternal and epidural pressure. The accuracy of epidural pressure monitoring was further reinforced by the infusion of a bulk volume of 16 ml normal saline administered at a rate of 1.94 ml/min, which showed not only an exact duplication of the cisternal pressure, but also a correlation coefficient of 0.98.

References


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