Epidural Anesthesia in the Normotensive
Pregnant Ewe:
Effects on Uterine Blood Flow and Fetal Acid—Base Status

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Lumbar epidural anesthesia was administered to 12 normotensive pregnant ewes. Blood pressure was maintained by intravenous fluid infusion. Six ewes received anesthesia with 1.5 per cent 2-chloroprocaine with 1:100,000 epinephrine and the remaining six received 1.5 per cent 2-chloroprocaine without epinephrine. The sensory level of anesthesia was between the umbilicus and xiphisternum. Except for a transient 14 per cent decrease in uterine blood flow in the ewes receiving 2-chloroprocaine with epinephrine, uterine blood flow remained near control values and was sufficient at all times to maintain stable fetal acid–base and blood gas values. Provided blood pressure and uterine blood flow were stable, the percentage of uterine blood flow distributed to the placenta in the absence of uterine contractions was not altered by epidural anesthesia or by addition of epinephrine to the anesthetic solution. (Key words: Anesthetic techniques, peridural; Anesthesia, obstetric; Uterus, blood flow.)

EPIDURAL ANESTHESIA, with its associated sympathetic blockade, can produce systemic hypotension. In the parturient, hypotension causes a proportional decrease in uterine blood flow, which may induce fetal asphyxia. It is generally assumed that if hypotension does not accompany epidural anesthesia, uterine blood flow will not change. It is conceivable, however, that sympathetic blockade could result in a redistribution of regional and organ blood flow, thereby decreasing or increasing uterine blood flow.

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To determine which of these alternatives in fact occurs, we investigated the effects of epidural anesthesia on the level and distribution of uterine blood flow as well as on fetal well-being in normotensive pregnant ewes. In addition, we asked whether epinephrine added to the anesthetic solution might, by systemic adrenergic activity, also modify uterine blood flow.

Method

Studies were performed on 12 pregnant ewes near term (mean gestational age 130 days; range 126–134 days). Each ewe carried a single fetus. All animals underwent preparatory surgery while anesthetized with halothane in oxygen (fig. 1). Polyvinyl catheters (#8 French, 0.105” OD) were placed via groin incisions into both maternal femoral arteries and one femoral vein and, via the internal jugular vein, into the right atrium. One arterial catheter was used for continuous recording of maternal blood pressure and heart rate, while the other arterial catheter was used for arterial blood sampling and, together with the right atrial catheter, for the measurement of cardiac output by the cardiogreen dye-dilution technique. In two animals subsequently to undergo studies of uterine blood flow distribution with radionuclide-labelled microspheres, a catheter was inserted into the left ventricle via the common carotid artery. A Statham pre-calibrated, gated sine-wave electromagnetic flow probe was secured to a branch of the uterine artery via a midline abdominal incision. Through a small hysterotomy incision a polyvinyl catheter (#4 French, 0.053” OD) was inserted into a fetal hind-limb artery for arterial sampling and measurement of blood pressure and heart rate. An additional polyvinyl catheter (#8 French, 0.105” OD) was placed in the amniotic
fluid cavity for pressure measurements. The uterus was closed and the suture line oversewn to prevent leakage of amniotic fluid.

At least 24 hours elapsed between the above preparations and the conduct of a study. Throughout each experiment maternal and fetal blood pressures and pulse rates were recorded using Statham P23 Db strain gauges connected to a Grass polygraph recorder. Uterine blood flow was measured using a Statham SP 2022 blood flowmeter.

Maternal and fetal arterial blood gases and pH were measured immediately after sampling using an Instrumentation Laboratories 313 Blood Gas Analyzer and corrected for temperature measured by a Yellow Springs rectal probe. Maternal and fetal base excess values were obtained using the Severinghaus slide rule.²

During each study the conscious ewe was placed in the lateral decubitus position and 100 per cent oxygen was administered by face mask at 5 l/min to minimize the effects of possible atelectasis. One liter of lactated Ringer's solution was infused intravenously into each ewe before the start of an experiment, and additional fluids were given as required to maintain normal maternal blood pressure. Vasopressors were not given.

Each study was subdivided into three periods. The first, a control period, lasted 30 to 45 minutes, during which time the maternal and fetal cardiovascular and acid-base values were stable. This was followed by a period of epidural anesthesia. Six of the ewes studied received anesthesia with 6 to 8 ml of 1.5 per cent 2-chloroprocaine (Nesacaine) containing 1:100,000 epinephrine (60–80 µg), while the remaining six ewes were given an identical anesthetic solution without epinephrine. Anesthetic solutions were selected at random. The sensory level of epidural anesthesia, as determined by lack of response to a 30-volt electrical stimulus applied to the skin, was established midway between the umbilicus and the xiphisternum. The mean duration of anesthesia was 60 to 75 minutes, being 15 minutes longer in those animals receiving the epinephrine-containing anesthetic. Measurements taken following the return of a response to the electrical stimulus were used as post-anesthesia controls.

In two animals the distribution of blood flow to the uterus was studied by the technique of Rudolph and Heymann.² Carbonized microspheres, 25 µm in diameter, labelled with

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**Table 1. Control Maternal Cardiovascular Data (Means ± SE)**

<table>
<thead>
<tr>
<th></th>
<th>Mean Blood Pressure (torr)</th>
<th>Pulse Rate (Beats/Min)</th>
<th>Cardiac Output (l/Min)</th>
<th>Stroke Volume (ml)</th>
<th>Total Peripheral Resistance (dynes·sec·cm⁻⁵)</th>
<th>Uterine Blood Flow (ml/Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroprocaine</td>
<td>105 ± 6.0</td>
<td>100 ± 10.5</td>
<td>6.64 ± 1.03</td>
<td>73.7 ± 32.4</td>
<td>1348 ± 199</td>
<td>490 ± 221</td>
</tr>
<tr>
<td>Chloroprocaine + epinephrine</td>
<td>100 ± 5.3</td>
<td>100 ± 9.1</td>
<td>8.05 ± 1.14</td>
<td>82.6 ± 12.0</td>
<td>1102 ± 145</td>
<td>663 ± 174</td>
</tr>
</tbody>
</table>
\(^{89}\)Nb, \(^{85}\)Sr, and \(^{125}\)I, were injected into the left ventricle 30 minutes after the start of the control, epidural, and post-epidural periods, respectively. At the end of the study placental cotyledons, myometrium, and amnion were removed. The tissue was weighed, carbonized, and transferred to vials for radioactivity analysis.

Results

Control values for blood pressure, pulse rate, and uterine blood flow are means of determinations made at 5-minute intervals during the control period (tables 1 and 2), while control values for cardiac output, stroke volume, total peripheral resistance (table 1), and acid-base data (table 3) are means of determinations taken at 15-minute intervals. Values during the epidural and post-anesthesia periods are given for 15-minute intervals. Values for blood pressure, pulse rate and uterine blood flow in each interval represent the means of three consecutive 5-minute determinations. All cardiovascular values during the epidural and post-anesthesia periods are given as percentage changes from control. Analysis of variance, two-way classification, was used to examine the data for statistical significance. Student's t test for paired data was used where indicated. Student's t test for unpaired data was used to compare data from ewes receiving epinephrine with data from those not receiving epinephrine. \(P < 0.05\) was considered significant.

In all ewes the maternal blood pressure was maintained within 10 per cent of the control value by intravenous administration of 5 per cent dextrose in lactated Ringer's solution before and during the epidural anesthesia (fig. 2). A total of 2,058 ml \pm 265 (SE) was infused into animals receiving epinephrine, and 1,942 ml \pm 280 into the remaining animals. These volumes were not significantly different.

Uterine blood flow was not changed from control either during or following the epidural anesthesia with the plain anesthetic solution. However, the use of epinephrine decreased flow a small (14 per cent) but significant amount compared with both control values (\(P < 0.05\)) and the values from the...
<table>
<thead>
<tr>
<th>Chlorpromazine and ephedrine</th>
<th>Control</th>
<th>During Epidural Anesthesia</th>
<th>After Anesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (units)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal</td>
<td>7.48 ± 0.01</td>
<td>7.47 ± 0.02</td>
<td>7.49 ± 0.02</td>
</tr>
<tr>
<td>Fetal</td>
<td>7.35 ± 0.01</td>
<td>7.32 ± 0.02</td>
<td>7.34 ± 0.02</td>
</tr>
<tr>
<td>Pco2 (torr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal</td>
<td>36.2 ± 1.0</td>
<td>32.5 ± 2.3</td>
<td>34.1 ± 1.3</td>
</tr>
<tr>
<td>Fetal</td>
<td>48.8 ± 1.3</td>
<td>50.4 ± 1.5</td>
<td>52.0 ± 2.6</td>
</tr>
<tr>
<td>Pa (torr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal</td>
<td>299 ± 18</td>
<td>250 ± 41</td>
<td>261 ± 28</td>
</tr>
<tr>
<td>Fetal</td>
<td>25.0 ± 0.8</td>
<td>24.0 ± 1.9</td>
<td>24.2 ± 1.7</td>
</tr>
<tr>
<td>Base excess (mEq/l)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal</td>
<td>3.4 ± 0.5</td>
<td>-0.2 ± 1.8</td>
<td>2.7 ± 1.3</td>
</tr>
<tr>
<td>Fetal</td>
<td>0.2 ± 0.5</td>
<td>-0.5 ± 1.3</td>
<td>0.5 ± 0.6</td>
</tr>
</tbody>
</table>

Table 3. Maternal and Fetal Blood-Gas and Acid-Base Values before, during and after Epidural Anesthesia (Means ± SE)
Fig. 2. Effects of epidural anesthesia (denoted by shaded area) on mean maternal blood pressure and uterine blood flow. All values subsequent to each control value are given as mean percentage changes with standard errors.

group that had not received epinephrine ($P < 0.01$). This decrease in flow occurred during the first 15-minute interval after confirmation of anesthesia. It was transient, and flow returned to control values between 15 and 30 minutes after initiation of the block (fig. 2).

In all ewes epidural anesthesia decreased total peripheral resistance. Tachycardia and an increase in cardiac output occurred (fig. 3). Changes in stroke volume were equivocal. During the first 15 minutes of anesthesia the two solutions affected total peripheral resistance and cardiac output similarly, but only in those sheep receiving anesthetic with epinephrine did the changes differ significantly from control. Maternal pulse rates during the early part of anesthesia increased similarly with both solutions. However, 45 and

Fig. 3. Effects of epidural anesthesia (denoted by shaded area) on maternal total peripheral resistance, pulse rate, cardiac output, and stroke volume. All values subsequent to each control value are given as mean percentage changes with standard errors.
60 minutes after induction of anesthesia pulse rates were higher when epinephrine was omitted from the anesthetic solution. We did not perform comparative analysis of these values since only three sheep in this group remained anesthetized at 45 minutes.

Small (5 to 10 per cent) but significant decreases in fetal blood pressure and pulse rate (table 2) occurred during anesthesia in those animals anesthetized without added epinephrine. These decreases persisted into the period after anesthesia. With the addition of epinephrine, fetal blood pressure remained stable while pulse rate tended to increase.

Maternal or fetal arterial oxygen, carbon dioxide, pH, and base excess did not change during the epidural anesthesia (table 3) in either the presence or the absence of epinephrine.

Microsphere studies were performed in two sheep, one of which received epinephrine and the other of which did not. In both sheep the percentage of total uterine arterial flow distributed to the placenta (84 per cent) was unchanged by epidural anesthesia (fig. 4).

Discussion

We have examined the effects of epidural anesthesia on uterine blood flow and fetal well-being independent of the systemic hypotension sometimes induced by such anesthesia. The only previous work on this subject was presented by Brotanek and co-workers. They found that epidural anesthesia with mepivacaine (no epinephrine) did not change uterine blood flow in pregnant women in labor provided the blood pressure did not fall. These studies, performed with a heated thermistor probe, allowed only a qualitative estimate of the changes in flow. No fetal cardiovascular or acid–base data were obtained.

The stability of uterine blood flow and fetal acid–base and blood-gas values during epidural anesthesia in the normotensive ewe in the absence of uterine contractions is reassuring. It suggests that no adverse effect is induced by this form of anesthesia per se. The fetal cardiovascular system also remained relatively stable, although fetal pulse rate and blood pressure decreased slightly (as much as 10 per cent) in those animals receiving 2-chloroprocaine without epinephrine.

Although fetal oxygenation and acid–base status remained stable regardless of the anesthetic solution used, we did find a significant though transient decrease in uterine blood flow immediately after induction of anesthesia with the epinephrine-containing solution. This presumably was due to the effect of absorbed epinephrine.

Epinephrine absorbed from the epidural space has been shown to produce a beta-adrenergic response that becomes maximal 15 minutes after epidural injection. Similar cardiovascular changes were seen in our study of pregnant ewes following addition of epinephrine to the epidural solution. These sheep also showed a decrease in uterine blood flow during this period.

Small doses of epinephrine, while producing a generalized beta response, have indeed been shown to have an alpha-adrenergic
effect on the pregnant uterus. Rosenfeld and colleagues infused 50 to 100 μg epinephrine intravenously over a 5-minute period into pregnant ewes. While the systemic blood pressure did not change, they found reductions of blood flow to the uterus, pancreas, and skin overlying the mammary gland, with increased flows to skeletal muscle, spleen, and fat. They postulated that reproductive tissues in the pregnant ewe may be more sensitive to alpha-adrenergic stimulation than other tissues. A differential alpha response with redistribution of blood from the uterus may explain the cardiovascular effects seen in our study following administration of an epinephrine-containing anesthetic.

During late pregnancy in the ewe, placental flow constitutes 84 per cent of the total uterine blood flow, the remainder perfusing myometrium (3 per cent) and endometrium (13 per cent). It would appear from the two sheep studied that, provided blood pressure and flow are stable, epidural anesthesia per se does not modify the distribution of flow within the uterus. We did not investigate the possible effects of absorbed catecholamine on the distribution of flow when total flow is decreased. However, the fact that fetal blood-gas and acid-base values remained stable suggests that any redistribution either spared the placental vasculature or was so transient as to be of doubtful functional significance.

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References

Cardiac Physiology

PSYCHIATRY AND VENTRICULAR FIBRILLATION A 38-year-old man had a history of numerous episodes of ventricular premature beats, as well as two instances of ventricular fibrillation. Cardiac catheterization and coronary arteriography disclosed no abnormality. The patient had serious psychiatric problems at home; the presence of a psychiatrist as well as a psychiatric interview markedly increased the frequency of ventricular premature contractions. The incidence of ventricular extrasystoles increased during REM sleep and was controlled by beta-adrenergic blockade, diphenylhydantoin, and digitization. In addition, the patient was instructed in a technique analogous to that of transcendental meditation. Meditation was carried out twice daily in the presence of an oscilloscope monitor screen. The patient was soon able to control the frequency of ventricular extrasystoles by meditation. "On beginning to exhibit advanced grades of arrhythmias, he was able to abolish them by meditation." It would appear that this is an example of the importance of the central nervous system in the occurrence of sudden death. (Lown B, et al: Basis for recurring ventricular fibrillation in the absence of coronary heart disease and its management. N Engl J Med 294:623–629, 1976.)