COMPARISON OF ANESTHETICS ON INCIDENCE OF VENTRICULAR FIBRILLATION IN EXPERIMENTAL HYPOThERMIC VENTRICULOTOMY

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It is common observation that hypothermia predisposes to ventricular fibrillation, whether spontaneous or induced by direct mechanical or electrical stimulation. The latter is frequently encountered in experimental and clinical surgery of the ventricle at low heart temperatures. To date no absolute means of prevention has been found. Several reports have appeared which indicate that the incidence of spontaneous ventricular fibrillation, as well as the mean temperature of its appearance, may vary with the anesthetic employed for hypothermia induction. Under pentobarbital anesthesia the incidence is greater (and at a higher mean temperature) than under thiopental (1, 2) or ether (1). In addition there appears to be a critical temperature of about 25 C. above which spontaneous fibrillation does not occur regardless of the nature of anesthesia or the direction of temperature change (that is, during cooling or rewarming) (1, 3). However, no systematic studies have been reported to determine whether the incidence of induced fibrillation is also influenced by the nature of the precooling anesthetic or whether 25 C. is a critical temperature for induced vs for spontaneous ventricular fibrillation. The present study was undertaken to supply information on these points and is not concerned with other recognized variables, as pH and PCO₂ (4).

METHOD

Mongrel dogs of both sexes, weighing from 7 to 18 kg. were anesthetized with ether, pentobarbital, or thiopental. Artificial respiration was instituted immediately upon tracheal intubation. Deep esophageal temperature was measured in degrees centigrade with a Telethermometer (Yellow Springs Co., Ohio), equipped with a thermistor probe. Continuous visual and audio monitoring of heart action was achieved by means of an oscilloscope and loudspeaker in series with the electrocardiograph recording lead II. Following immersion in iced water (2 to 5 C.), an electrocardiographic record was obtained at each 5 C. drop in esophageal temperature and whenever the oscilloscope revealed any change in rhythm or pattern. The surgical procedures were

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performed as follows: At 1.5 C. above the desired operative esophageal temperature (generally 26 C., but also 30 C. and 20 C. as indicated below), the dogs were removed from the bath, whereupon the postimmersion temperature drift brought them to a stabilized temperature within one degree of that desired. A right thoracotomy was performed, the azygos vein tied off, the venae cavae clamped, and the pericardium widely opened. The right ventricle was opened with a 2.5-cm. incision, explored with the index finger and then sutured; following which the clamps on the venae cavae were slowly released, the chest closed, and the surviving animals were rewarmed to 30 C. in a water bath of 45 C. Artificial respiration was discontinued when it was confirmed in each case that the rewarmed animal was capable of independent respiration. The periods of circulatory occlusion were: 9 to 10 minutes at 26 C. and 20 C., and 5 to 6 minutes at 30 C.

**TABLE 1**

**INFLUENCE OF SEVERAL ANESTHETICS ON INCIDENCE OF VENTRICULAR FIBRILLATION DURING VENTRICULECTOMY AT LOW TEMPERATURES**

<table>
<thead>
<tr>
<th>Number of Experiments</th>
<th>Anesthetic</th>
<th>Surgical Temperature Degrees Centigrade ±1</th>
<th>Ventricular Fibrillation (per cent)</th>
<th>Procedures Inciting Fibrillation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Ether</td>
<td>26</td>
<td>47</td>
<td>I 3 II 4 III 0 IV 0</td>
</tr>
<tr>
<td>10</td>
<td>Pentobarbital</td>
<td>26</td>
<td>60</td>
<td>I 4 II 2 III 0 IV 0</td>
</tr>
<tr>
<td>10</td>
<td>Thiopental</td>
<td>30</td>
<td>40</td>
<td>I 3 II 0 III 1 IV 1</td>
</tr>
<tr>
<td>15</td>
<td>Thiopental</td>
<td>26</td>
<td>27</td>
<td>I 4 II 0 III 0 IV 0</td>
</tr>
<tr>
<td>10</td>
<td>Thiopental</td>
<td>20</td>
<td>60</td>
<td>I 3 II 0 III 2 IV 2</td>
</tr>
</tbody>
</table>

* Procedures inciting fibrillation:
  I—first minute of circulatory occlusion, or at incision of myocardium.
  II—during exploration or suturing of myocardium.
  III—within 5 minutes after release of occluded venae cavae.
  IV—later than III, during rewarining.

Ether anesthesia was induced by means of an open mask, and continued (after tracheal intubation) with a Wolfe bottle and shunt placed in series with the respirator. Initially, pentobarbital was administered intraperitoneally (33 mg./kg.), and additional required increments were given intravenously. In dogs subjected to thiopental anesthesia, a 1 Gm. per cent solution was administered intravenously to one-half of the group, and intraperitoneally to the other half. The latter proved more convenient, with no observable difference in the results, nor in the total thiopental required. In all cases anesthesia was maintained at a level just sufficient to prevent shivering.

**RESULTS**

These are summarized in table 1, and suggest that susceptibility to induced ventricular fibrillation is not significantly different under one
than under another of the three anesthetics tested; and if a critical
temperature exists, above which induced ventricular fibrillation does
not occur, it must lie above 30 C. The trends exhibited in relation
to the several anesthetics vis a vis induced ventricular fibrillation are
similar to those observed for the spontaneous variety (1, 2), but
statistically significant differences can not be demonstrated in these
series.

Since these experiments were performed, in part, to distinguish
between induced and spontaneous fibrillation, it appeared advisable to
indicate the exact initiating factor responsible for its appearance in
these experiments. The factors are classified in the table. With
three exceptions, fibrillation obviously appears to have been induced
by direct mechanical stimulation (incision, exploring, or suturing).
In the three apparent exceptions, fibrillation occurred during rewar-
ing, that is, after chest closure, when presumably there was no further
unnatural mechanical stimulation. It becomes a question whether
these instances should be classed as spontaneous or induced. It might
be suggested that the pull on the sutures by the beating heart could
be an adequate mechanical stimulus in a hypothermic heart.

**Discussion**

Although, as the data indicate, the susceptibility to induced fibrilla-
tion is already conspicuous at 30 C., spontaneous fibrillation rarely
occurs above 25 C. This suggests that only at the lower temperature
can the natural triggering mechanism (ectopic activity?) reach the
fibrillation threshold. In hypothermic cardiac surgery, however, the
mechanical stimuli involved can and do reach the fibrillation threshold.
Thus, susceptibility to fibrillation, whatever its nature, is a progressive
phenomenon, the threshold decreasing with temperature. This is in
accordance with the observations that susceptibility to calcium induced
fibrillation develops early in hypothermia (5), the susceptibility to
electrically induced fibrillation is much greater at 30 C. than at normal
temperature, and still greater at 25 C. (6). There is then the fact that
hypothermia predisposes to ventricular fibrillation. The difference
between spontaneous and induced fibrillation concerns only the trigger-
ing mechanism. For the former it is apparently spontaneous ectopic
activity and for the latter it is the ectopic activity created by an arti-
ficially applied stimulus. One could then theoretically block fibrilla-
tion either by prevention of ectopic action or by preventing those
changes which make the fibrillary process itself possible. This distinc-
tion appears to have been made pharmacologically (7) when it was ob-
served that quinidine prevented spontaneous fibrillation and the ap-
pearance of ectopic action, but failed to protect against induced fibrilla-
tion. Ambenostyl, on the other hand, exerted measurable protection
against both spontaneous and induced fibrillation but failed to block
ectopic action. Quinidine appears, therefore, to exert its protective action via an antiarrhythmic property while Ambonestyl protects via a direct antifibrillary action.

It has been stated that under thiopental anesthesia (8) the hypothermic heart exhibits a sudden pronounced decrease in rate at 22 to 19 C., forming an abrupt change in the slope of the rate-regression curve which occurs with temperature. This is ascribed to the shift of the pacemaker from the sinoatrial node to the atrioventricular node. We have observed the pacemaker shift frequently, though not invariably, under thiopental in this temperature range and lower, but unaccompanied by sharp changes in rate (9). We cannot account for the discrepancy in the two sets of observations.

**Summary**

The frequency of hypothermic ventricular fibrillation, when induced by ventriculotomy and repair, is not significantly different under thiopental, pentabarbital, or ether anesthesia, although the trends resemble those observed for the spontaneous variety. In addition, there appears to be no critical temperature (unless greater than 30 C.) above which mechanically induced fibrillation fails to occur. Spontaneous ventricular fibrillation rarely occurs at temperatures above 25 C.

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**REFERENCES**