Elective Countershock in Unanesthetized Patients with Use of an Esophageal Electrode

By E. M. McNally, M.D., E. C. Meyer, M.D., and R. Langendorf, M.D.

CONSIDERABLE attention has recently been shown in dispensing with general anesthesia during countershock.1-4 This problem has also interested us and the present report deals with our attempt at solving it by using an esophageal electrode.

Only a fraction of the energy administered to the patient during countershock by the usual, surface electrode technic is usefully consumed within the heart. The remainder is dissipated elsewhere, in driving current not only to and from the heart, but through pathways that circumvent it entirely. The distribution of electrical energy among these fractions is determined by the location of the electrodes on the chest and by the spatial configuration of the varyingly resistive tissues of the thorax. When electrodes are applied directly to the heart, depolarization is achieved with about 5 watt-seconds of energy; in clinical external countershock, even with optimal electrode placement and a good subject, energies of 50 watt-seconds or more are almost always necessary. Thus, the greater part by far of the administered energy is expended in extracardiac tissues where, since it does not participate in depolarizing the heart, it is wasted. Clinical external countershock is, then, at best an operation of appreciably low efficiency. The relevance of these considerations to the problem of avoiding the need for anesthesia is that it is precisely that fraction which is dissipated outside the heart which gives rise to the discomfort of countershock: it is current flow in tissues other than the heart—principally in skeletal muscles—and not depolarization of the heart itself that leads to the discomfort of the procedure. The problem, therefore, of dispensing with anesthesia reduces to that of increasing the efficiency with which electrical energy is delivered to the heart, in order that the extracardiac current flow may be decreased to a tolerable level.

Viewed this way, the problem of administering countershock to conscious patients is essentially similar to that of pacing the heart in a tolerable fashion without resort to intracardiac electrodes. Both problems have interested us and we have approached both in basically the same way, by using an esophageal electrode.*

Our purpose has been to achieve a greater proximity of the electrodes to the heart. Our technic has been to place one electrode in the esophagus, contiguous with the heart, and the other on the precordium. We hoped that this gain in electrical proximity would sufficiently improve the efficiency of energy delivery so that extracardiac current flow would fall to tolerable levels. The esophageal electrode consisted of bars, 22-gauge, tinned copper wire wound about the distal end of a 16 Levine tube so that it formed a coil 7 cm. long. This coil—the electrode proper—was then connected to one paddle of the Lown DC Cardioverter† by an insulated wire run up the lumen of the tube.

*Our experience with pacing with an esophageal electrode will be published elsewhere.
†Manufactured by the American Optical Company, Buffalo, New York.

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Work done during tenure (Dr. Meyer) as an Ehrlich-Krupnick Fellow.
ELECTIVE COUNTERSHOCK

Results

In a preliminary study, 20 shocks of 200 watt-seconds intensity were given in quick succession to six anesthetized dogs, with the use of the esophageal-precordial electrode arrangement. The animals were observed for 72 hours and then killed. No ill effects, either functional or anatomic, were discernible.

Our first human studies were designed to establish the order of magnitude of conversion energy with the esophageal technic. These patients were, therefore, all anesthetized. The esophageal electrode was passed to the level of the left atrium, an electrode was placed on the precordium, and light general anesthesia was induced with intravenous thiopental. Graded shocks of increasing intensity were then given until conversion had been accomplished.

Eight patients with chronic atrial fibrillation were studied. The age, diagnosis, left atrial size, and duration of fibrillation are listed in Table 1. In each case, the highest intensity shock failing to convert is tabulated in the sixth column, and the lowest intensity that achieved conversion, in the seventh. In no instance was an energy of more than 60 watt-seconds needed, and in all but two, 40 or less sufficed. Except for the first case, all of these patients would, on the basis of atrial size or duration of fibrillation, be classified as "difficult to convert."

Within 2 weeks of their transesophageal defibrillation, five of the eight patients in this group (no. 2-5, 7), having in the meantime reverted to atrial fibrillation, were defibrillated by the method of Lown with use of surface electrodes in the anteroposterior position. They were identically medicated and, as far as could be judged, were clinically in the same state at the time of the two conversions. In these five instances we were able to compare the energy requirements with the two technics. The highest energy shock that failed to convert is shown in the next-to-the-last column, and the converting energy, in the last column of Table 1. The energy required with the esophageal electrode technic averaged

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Table 1

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, yr.</th>
<th>Cardiac diagnosis</th>
<th>Duration of AF</th>
<th>Left atrial size</th>
<th>Shock energy (watt-sec)</th>
<th>Successful</th>
<th>Highest Energy Requiring Failure (watt-sec)</th>
<th>Surface Electrode Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>RH, HD, post-commissurotomy</td>
<td>1 yr.</td>
<td>3+4/4+</td>
<td>15</td>
<td>Success</td>
<td>200</td>
<td>E-Pr</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>RH, HD</td>
<td>8 yr.</td>
<td>1+4/4+</td>
<td>25</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>3</td>
<td>69</td>
<td>RH, HD</td>
<td>8 yr.</td>
<td>3+4/4+</td>
<td>30</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>4</td>
<td>57</td>
<td>RH, HD, MI</td>
<td>9 mo. (7)</td>
<td>3+4/4+</td>
<td>60</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
<td>RH, HD, MI</td>
<td>9 yr.</td>
<td>3+4/4+</td>
<td>60</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>6</td>
<td>43</td>
<td>Unknown</td>
<td>1 yr.</td>
<td>3+4/4+</td>
<td>40</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>7</td>
<td>43</td>
<td>RH, HD, MI</td>
<td>6 yr.</td>
<td>3+4/4+</td>
<td>40</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>RH, HD</td>
<td>7 yr.</td>
<td>3+4/4+</td>
<td>25</td>
<td>Failure</td>
<td>100</td>
<td>E-Pr</td>
</tr>
</tbody>
</table>

RH, hypertensive atherosclerotic heart disease; HD, rheumatic heart disease; MI, mitral insufficiency; MS, mitral stenosis; AI, aortic insufficiency; AP, anteroposterior.
less than half of that needed when the conventional, surface placement was employed.

We next studied transesophageal countershock in five unanesthetized patients (table 2). Fifty or 75 mg. of Demerol were given 1 hour before the procedure. The esophageal and precordial electrodes were located as in the first group. Each patient was given one shock. The intensity was 40 watt-seconds except in the first case, in which it was 30. All patients had difficulty describing their sensations; their own phrases are quoted in table 2. Severe pain was expressly denied by all of them. When asked how they would feel about having the procedure repeated, should the need arise, none objected. Four of the five had previously received countershock under anesthesia. All but one of the four said that they would prefer to do without anesthesia.

All patients given esophageal countershock stayed in the hospital for 48 hours after the procedure and have been followed as outpatients for from 2 to 8 months. They have been repeatedly questioned as to the occurrence of nausea, anorexia, hiccups, dysphagia, or symptoms of esophagospasm. These complaints have been consistently denied by all.

Discussion

From these data the following inferences seem justified. The conversion energy for atrial fibrillation with the esophageal electrode is less than half that when the conventional, surface electrode placement is used. With the esophageal technic, all but the most unlikely candidates, viz., patients in whom elective defibrillation would, on other grounds, not be considered, will be converted by a shock of 40 watt-seconds in all likelihood. Shocks of 40 watt-second intensity are tolerable to the conscious patient and have no discernible ill effects, early or delayed.

An esophageal electrode was successfully used for ventricular defibrillation in dogs. Our aim in using it in man was to reduce the electrical energy sufficiently to permit application of countershock without anesthesia. Other workers have also sought a means of dispensing with anesthesia during countershock. One approach, quite different from our own, has been to explore the use of non-anesthetic premedication. Slodki and his group, for example, have employed a modified form of twilight sleep. Though the final solution to the problem may well lie along such lines, most attempts have been directed toward reducing the energy requirement, since the discomfort seems closely to parallel shock intensity. Lown, by substituting an anteroposterior electrode placement for the earlier, anterolateral one, achieved impressive reductions in energy requirements. Still further reductions have been reported by using larger electrodes. With these modifications in technic, a large percentage of patients have been found to convert with shocks of less than 100 watt-seconds, energies within a range tolerable to unanesthetized patients. Before undertaking cardioversion without anesthesia in a given case, however, one should be virtually certain that a single shock well within the tolerable range will succeed, for repeated shocks, even of "tolerable" intensity, are poorly withstood for psychologic reasons. Moreover, it is undesirable to have to call on an anesthetist in the midst of the procedure. Only in certain patients, namely, those with thin chests, small atria, and either atrial flutter

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Shock intensity (watt-sec.)</th>
<th>Subjective response</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>30</td>
<td>&quot;Shock in stomach&quot;</td>
</tr>
<tr>
<td>B</td>
<td>M</td>
<td>40</td>
<td>&quot;Bursting (in epigastrium)&quot;</td>
</tr>
<tr>
<td>C</td>
<td>M</td>
<td>40</td>
<td>&quot;Hit in chest&quot;</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>40</td>
<td>&quot;Explosion in chest&quot;</td>
</tr>
<tr>
<td>E</td>
<td>M</td>
<td>40</td>
<td>&quot;Kicked in chest&quot;</td>
</tr>
</tbody>
</table>
or recent atrial fibrillation, is success with a single, tolerable shock certain enough to justify undertaking the procedure without anesthesia. In this group, the conventional technic would appear to be satisfactory in unanesthetized patients and there would seem to be no reason for using the esophageal technic. There are many patients, however, in whom the likelihood of failure of conversion with an initial, tolerable shock with the conventional method is great enough that it would be unwise to undertake countershock without anesthesia. It is in this group that the esophageal technic, with its greatly reduced energy requirements, may find its chief usefulness.

The present report is a progress note. We plan to investigate further the role of the esophageal electrode in elective countershock. Energy requirements can probably be still further lowered by certain modifications in the technic. If this method allows elective cardioversion to be attempted without anesthesia in a significant number of patients who require it with the conventional method, it will expand the flexibility of cardioversion. More experience with both technics without anesthesia must be accumulated before the proper approach to be used in a given patient can be clearly defined. The present study does, however, suggest that cardioversion can be accomplished comfortably in unanesthetized patients with the esophageal electrode.

Summary

A new electrode arrangement for the administration of elective direct-current countershock was studied, in which one electrode was placed in the esophagus, adjacent to the heart, and the other on the precordium.

Thirteen patients with chronic atrial fibrillation were converted to sinus rhythm by the esophageal technic. Though the majority were, on clinical grounds, difficult cases for conversion, 11 were converted with shocks of 40 watt-seconds or less, and two with 60, after 40 failed. Five patients were defibrillated by both the esophageal and the conventional, anteroposterior chest technics; the energy requirement with the esophageal method averaged less than one third of that with the conventional one. Four patients received 40, and one 30 watt-second shocks without anesthesia; all five tolerated the shocks well, and three of four who had had countershock previously under anesthesia, expressed preference for the esophageal technic without anesthesia in the future. All patients were observed carefully for any symptoms suggestive of esophageal injury or dysfunction. None such occurred, either immediately or within 4 months.

We conclude that this technic may have a place in elective countershock in that it may allow cardioversion to be undertaken in many patients who would otherwise require anesthesia.

Acknowledgment

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References
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