

# SUCCINYLBCHOLINE IN ELECTROSHOCK TREATMENT

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In the fifteen years since its introduction by Bini and Cerletti<sup>1</sup> electroshock treatment has steadily gained in popularity. It is the treatment of choice in the affective psychoses and has wide application in many other conditions. The singular lack of fatalities associated with the treatment in physically sound people is one of its major virtues<sup>2, 3</sup>.

However, lesser complications are not infrequent even under the best conditions. Compression fractures of the thoracic vertebrae are probably more common than is realized<sup>4</sup>. While authors have some difficulty agreeing on the incidence of these fractures, their frequency appears directly related to the diligence with which they are sought. In one recent series with careful clinical and radiological examinations 20% of the patients had sustained fractures<sup>5</sup>. Fortunately these fractures rarely lead to serious disability. Surely though, the dictum of nil docers must not be too lightly disregarded. Fractures of long bones, and the occasional cardiovascular tragedy are infrequent but ominous possibilities.

Where, however, the patient is suffering from certain physical abnormalities electroshock may be a highly dangerous procedure. Among these are severe cardiac disease, active, tuberculosis, and abnormalities of the skeletal system. While it is true that greater experience with electroshock has enabled us to take a more liberal view of the contraindications, its use in the presence of these conditions involves considerable danger. Frequently it is necessary to take a calculated risk since electroshock may prove a life-saving measure in suicidal depressions. Much energy, therefore, has been devoted to reducing the violence of electrical convulsions. A number of machines have been devised which produce softer seizures and less physiological disturbance. These are rarely sufficient though, to reduce the hazards very much.

In 1941 Bennet<sup>6</sup> used a preparation of curare to modify the convulsions by paralysis of the musculature, with great success. Curare and allied preparations, however, are somewhat unpredictable in their effects, produce too durable a paralysis and have caused many fatalities<sup>7, 8, 9</sup>. They often have undesirable side effects<sup>10</sup>. Newer substitutes for curare, such

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as decamethonium, gallamine, are open to the same objections and in some cases satisfactory antidotes are not known. In Succinylcholine the answer has apparently been found.

Succinylcholine was discovered by Hunt<sup>11</sup> in 1906. Chemically it is diacetylcholine. It is easily soluble in water to form a slightly acid solution which is moderately unstable at room temperature. For this reason it is better kept under refrigeration. Both the iodide and the chloride are active but the latter is preferable.

Succinylcholine acts upon the neuromuscular junction causing a depolarization of the motor end-plate membrane<sup>12, 13</sup>. There is an initial stimulation of the muscle following intravenous injection, seen clinically as fibrillation and myoclonic jerks, and then a complete paralysis of short duration. The drug is completely hydrolyzed by the cholinesterase of the blood and tissues into succinic acid and choline—two harmless metabolites in a few minutes<sup>14, 15</sup>. Where cholinesterase is diminished or inhibited (neostigmine) the action may be prolonged. Because of its rapid destruction Succinylcholine is only effective by the intravenous route. Meyrhofer<sup>16</sup> demonstrated by a series of self-experiments that Succinylcholine acts peripherally. It does not produce loss of consciousness or changes in the sensory systems. There is evidence from animal experiments that large doses may produce a mild effect on the medullary respiratory center<sup>17</sup>. Reports of lasting apnea following prolonged administration perhaps indicate that this central effect occurs in man also, though most likely cholinesterase depletion is responsible. In clinical doses toxic effects are not seen. Dogs have been given up to 450 times the paralytic dose without ill effect<sup>19</sup>. Even large doses do not disturb the autonomic ganglia. For all practical purposes the drug causes only a neuromuscular blockade of brief duration.

Succinylcholine has been used in a variety of clinical procedures. Von Dardel and Thesleff, in 1951<sup>20</sup>, reported using it in many surgical operations with good results. Holmberg and Thesleff<sup>21, 22</sup> gave Succinylcholine iodide to over 136 patients prior to electroshock treatment. They administered doses of 0.3 mg/kilo. together with thiopental after premedication with atropine. Patients were kept well-oxygenated throughout, but the authors noted that this appeared to prolong the convulsions. Aside from hiccough and stridor in a number of patients (probably due to thiopental) there were no ill effects and adequate muscular relaxation was obtained. Most patients had soft grand mal seizures without the usual initial flexor spasm. At about the same time Arnold et al<sup>23</sup>, in Vienna, also reported on its use in electroshock. In the past year there have been several reports of its use in anesthesia. Relaxation during surgery, orthopedic manipulations and even delivery is achieved by a 0.1 or 0.2% continuous intravenous infusion of Succinylcholine in saline. The depth of relaxation may be simply varied from minute to minute as the occasion demands.

## CLINICAL STUDY

This investigation deals with an unselected series of 46 patients, 39 women and 7 men, treated consecutively by the author in the Medical School Hospital this year. Over half the patients were older than 45, and one quarter were 55 or above. Clinical diagnoses included depression, involuntional melancholia, hypomania, schizophrenia, and psychosis with organic brain disease. Of the 46 patients 32 were in good health and 14 had one or more somatic lesions. In 8 patients these were of such a nature that electroshock was considered a dangerous procedure (see table 1). All patients received a complete physical examination, electrocardiogram and X-rays of the thoracic spine, before treatment.

A total of 414 treatments was given. The number per patient ranged between 3 and 23, with an average of 9. In most cases they were given on alternate days but a few patients received two on the same day.

## TECHNIQUE

The patient was not premedicated in any way, dentures were removed but other prostheses, casts and clothing left untouched. An examination couch or stretcher was used without special support. No attempt was made to hold the patient during the seizure. Because of the rapid onset of the paralysis even violent patients required no restraint apart from that necessary to make the injection. A Rahm apparatus delivering 120 volts for .8 seconds was used without variation of the settings throughout. Means of delivering oxygen through a well-fitting mask with a large bag attached for controlled respiration under positive pressure and an electrical suction machine and a supply of airways formed the necessary equipment.

Succinylcholine chloride (Sudexol\* is put up in 20 cc. vials with 20 mg. per cc.) was given intravenously in an initial dose of 20 mg. (1 cc.). Injection is made rapidly. Within 10-20 seconds generalized fibrillation of the muscles appears. After about 25 seconds paralysis appears usually associated with myoclonic jerkings of limbs and trunk. There is a brief increase in the depth of respiratory movements before the intercostal and diaphragmatic muscles are paralyzed, and the shock is given, through bitemporally-placed electrodes. With the first treatment a mouth gag is customarily used, but this is rarely necessary in later treatments. As the current passes a momentary spasm of the neck muscles is seen without displacement of the body. The ensuing convulsion varies from a very gentle grand mal seizure to a barely perceptible twitching of orbicular muscles of the eyes and lips, of about 30 seconds duration. In most cases respiration has started spontaneously before the conclusion of the seizure. When it has not, oxygen is administered with manual inflation of the lungs if necessary for a minute or so. Respiratory movements, shallow at first, are back to normal depth within 3 minutes in the average case. Consciousness appears to be regained more quickly than with unmodified electroshock and none of the 406 treatments was followed by a severe confusional state. Recovery from the paralysis is immediate and complete. After the first treatment the dose of Sudexol is adjusted

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\* Sudexol brand Succinylcholine for this study was kindly supplied by Dr. L. E. Josselyn of Abbott Laboratories Inc., Chicago, Illinois.

to produce the best response. Most patients require 20 or 25 mg. A few achieve good relaxation with 15 mg. and some require up to 35 mg. One patient had fair relaxation with 10 mg. and another who received 100 mg. had completely recovered within 7 minutes, illustrating the wide margin of safety. The dose is adjusted to produce a seizure limited to clonic movements of the legs, and facial muscles. In patients with severe cardiovascular disease it is increased to permit only slight twitching of the facial muscles.

The whole procedure takes about 5 minutes, and the physician with one nurse can conveniently administer the treatments.

In the first 50 treatments of the series an injection of thiopental (average dose 0.25 gm.) was given before the Succinylcholine in the belief that the onset of Succinylcholine paralysis was painful. Following a fatality this practice was discontinued. With thiopental, treatments lasted longer, more oxygen was required, and recovery was delayed.

#### RESULTS

The therapeutic value of electroshock is undisturbed by Succinylcholine. All the depressive patients recovered or were greatly improved. Sixty per cent of the schizophrenics were more or less improved (many were chronic patients). Responses in the other categories were as expected. One patient died (discussed below).

Five of the patients (three of whom had myocardial disease) had serial electrocardiographs and blood pressure recordings throughout their treatments. No significant change was noted in either, before, during, or after the seizure.

Six of the patients spontaneously complained of a "choking feeling" after the injection and five others mentioned it when questioned.

Superficial observation of the patient's grimacing and jerking during the induction of paralysis might indicate that they were suffering pain. It is not pain but momentary stimulation of the neuromuscular junctions which causes this. If Succinylcholine is accidentally injected into the tissues it is quite harmless. The proper intravenous dose may be safely given immediately. Similarly a second dose of Succinylcholine may be administered if the first does not produce the required degree of relaxation, of the electric shock has been delayed too long. Of the 15 patients who had received electroshock previously without Succinylcholine 10 preferred to have Succinylcholine, one did not, and 4 could not say. Only four of the patients said that the muscular twitchings prior to paralysis were painful, and few complained of muscular tenderness afterwards. It is not felt that the unequal sex distribution in the series has influenced the results. No difference in the response of Succinylcholine between men and women was detected.

None of the 14 poor-risk patients suffered any ill-effects. This was particularly true of the eight patients where unmodified electroshock would have been considered hazardous. Details are given in table 1.

Table 1 — Details of the eight poor-risk patients.

	Sex	Age	Mental status	Somatic status	Dose of Succinylcholine	No. of treatments	Seizure *	Result
MB	Colored male	52	Recurrent Depression Actively suicidal	Ruptured intervertebral disc (LV) with partial paraplegia	25-30 mg	6	1 to 3	Recovery. No X-ray change in spine. No increased pain.
CB	White male	71	Actively suicidal Depression with cerebral arteriosclerosis	Cerebral arteriosclerosis Coronary disease. Recent Cerebral hemorrhage	25-40 mg	11	2 to 4	Recovery from Depression.
ED	White female	35	Paranoid Schizophrenia	Fracture dislocation of neck of humerus occurred during EST without Succinylcholine	30 mg	3	4	No change. No X-ray change in shoulder. No displacement of cast.
RR	White female	67	Reactive Depressive Actively suicidal	In plaster cast Hypertension 280/130 Detachment of Retina (replaced)	30-35 mg	12	3 to 4	Much improved. BP fell to 220/110. No damage to eyes.
DG	White female	30	Paranoid Schizophrenia with Depression	Fractures of vertebra T4 and T5 with EST 2 weeks previously	20 mg	6	1	Some improvement. Patient complained of back pain before but not after treatment. X-ray unchanged.
MG	White female	53	Involuntional Melancholia	Angina pectoris. Severe generalized arteriosclerosis	30 mg	10	4	Excellent result. Pain not increased.
MN	White female	73	Involuntional Melancholia Actively suicidal	Arteriosclerotic heart disease. Aortic incompetence. BP 310/50 Pellagra	35-40 mg	14	3	Good recovery, after one week of confusion. BP 230/60 after treatment.
EA	Colored female	26	Schizophrenia Catatonic excitement	Fractures of vertebra T5, T6, T7 from previous EST	25 mg	18	3	Improved. No complaint of pain. X-ray unchanged.

\* Key to type of seizure.

1. gentle generalized tonic-clonic. 2. mild generalized clonic only. 3. clonic movements of feet and face only. 4. twitching of mouth and eyelids.

## COMPLICATIONS

In 44 of the patients no complications were encountered. Prolonged apnea did not occur, even with a dose of 100 mg. (given experimentally). Excessive salivation did not prove troublesome, and did not seem greater than is found in unmodified electroshock due to vagal stimulation.

Complaints of unpleasant sensations were not obtrusive and not sufficient to justify the increased risk of thiopental anesthesia. There were no complaints of pain in the back suggestive of fracture. Twenty-one patients were X-rayed at the completion of the course. In those without previous evidence of fracture none was demonstrable. In the two patients with previous vertebral fractures no further change was seen. This was true also of patient ED who sustained a fracture dislocation of the humerus in her first treatment without Succinylcholine and who had arm in a plaster cast.

It was the impression of the staff that patients as a whole showed less apprehension of the electroshock treatments than is usually seen, though this was not critically substantiated.

The patient who died was a 56 year old colored woman with chronic schizophrenia. The pretreatment electrocardiogram and physical examination showed no abnormality. In her first treatment she received 0.25 gm. of thiopental with 25 mg. of Succinylcholine. Relaxation was moderate and she had a gentle grand mal convulsion. Respiration started spontaneously within one minute of the shock jaw tonus returned and she appeared to be making a normal recovery. Two minutes later the pulse became rapid and weak and respiration ceased. Artificial respiration intracardiac adrenaline, and direct cardiac massage performed within 8 minutes failed to restore the heart beat. Autopsy permission could not be obtained. Later it was learned that the patient had received 0.4 gm. of phenobarbital some hours before for sedative purposes. The exact cause of death cannot be stated. It is not felt that it should be attributed to Succinylcholine however, since respiration did return for a short period as did muscle tone in the jaw muscles. Possibly death was due to an abnormal sensitivity to thiopental in conjunction with the previous barbiturate dosage.

## DISCUSSION

It is difficult to restrain enthusiasm about the use of Succinylcholine in electroshock treatment. The ease of administration, rapid and uniform effect, simple controllability of the amount of relaxation, prompt and complete destruction within the body into harmless metabolites, and the lack of side-effects make it ideal for our purpose.

A word of caution is important. Succinylcholine is a very powerful drug. With experience and proper precautions there appears so far to be no danger, providing that the means to secure adequate oxygenation of the lungs is at hand.

In this series of cases including 8 very poor risks, no untoward happenings were encountered. Some authors have written of prolonged apnea following the use of Succinylcholine in anesthesia<sup>26, 27, 28</sup>. However larger doses were given by continuous intravenous infusion over long periods. Some of these patients were ill-advisedly given prostigmine in addition, which intensifies the action of the drug<sup>26, 29</sup>. Bourne, in a series of 546 surgical anesthetics, had 5 patients develop prolonged apnea<sup>18</sup>. He investigated the plasma cholinesterase values and found that in these 5 patients the blood titer was less than 50% of normal. Succinylcholine is hydrolyzed by the pseudo-cholinesterase of the plasma (and perhaps by the true acetyl-cholinesterase of the red cells). In chronic liver disease and malnutrition of severe degree cholinesterase values may be low<sup>30</sup>. Several patients in this series were very undernourished but showed no prolongation of the paralysis. With single doses it is probably unlikely that trouble will arise from this source. It has been suggested that transfusion of whole fresh blood or plasma (with a normal cholinesterase titer) should be given in cases of prolonged apnea<sup>31</sup>. Some of the new organic insecticides containing phosphorus, e.g. tetraethyl pyrophosphate, inactivate cholinesterase. Caution should be used in giving Succinylcholine to those known to have been recently exposed to these chemicals<sup>32</sup>.

Hitherto workers have used short-acting barbiturates with Succinylcholine<sup>18, 21, 22, 23</sup>. This has not been found necessary. The first few patients in this series received an average of 0.25 gm. thiopental just before the Succinylcholine. There were no advantages and the risk is greater. Succinylcholine alone, did not result in more complaints from the patients. It is conceivable that a particularly apprehensive patient might do better with the anesthetic. It should be mentioned here that thiopental (an alkaline solution) rapidly destroys Succinylcholine. Even when they are injected separately more Succinylcholine is often necessary to produce the required degree of relaxation.

It is our impression that the period of confusion during recovery from electroshock is shortened when Succinylcholine is used. This impression has yet to be verified by controlled experiments. In none of the treatments in this series did the confusional period last more than 15 minutes and in most cases was very brief.

The degree of relaxation is easily varied but is fairly constant in any one patient for a given dose. In relatively healthy patients 15-25 mg.

of Succinylcholine will reduce the convulsion to a gentle generalized or localized seizure. Total paralysis of the musculature is usually obtained with 35-40 mg. In patient ED with her right arm and shoulder in a plaster cast this was achieved with only 30 mg.

There is no antidote to Succinylcholine. Except in the rare patient with diminished plasma cholinesterase there would be no occasion for one. Here, as mentioned above, a transfusion of whole blood will provide the necessary cholinesterase supplement. Neostigmine and Tensilon, antidotes to other relaxants will intensify its effect similarly, procaine which competes with Succinylcholine for cholinesterase is contraindicated. It is worth while mentioning however, that Succinylcholine will diminish the effect of curare, since they have antagonistic actions upon the motor end-plate membrane.

The use of Succinylcholine in the many patients in this series who were in good physical condition may be considered unjustified. Undoubtedly the majority of them would have done well with plain electroshock. Statistics, however, indicate that a certain percentage of them would have sustained vertebral fractures (unpleasant for the patient and embarrassing for the doctor). It is our opinion that where proper facilities are available Succinylcholine is a very desirable addition to the technique of electric shock treatment. In the presence of cardiovascular or skeletal disease its use becomes mandatory.

#### SUMMARY

Electroshock treatment not infrequently leads to vertebral fractures and other complications. Where cardiovascular or skeletal disease exists, its use though desirable, may be fraught with danger.

The search for muscle relaxants to dampen the violence of the electrical convulsion has culminated in Succinylcholine. Injected intravenously as the chloride it produces a rapid paralysis of the musculature. Complete and permanent recovery occurs within a few minutes because of the quick destruction of the drug by cholinesterase.

A series of 416 treatments in 46 patients is reported. Somatic pathology in 8 of these electroshock would have been contraindicated. With Succinylcholine all patients made an eventful recovery. The discomfort of Succinylcholine is slight and not sufficient to require the use of intravenous anesthesia. One death is reported but evidence indicates that this may not be attributed to Succinylcholine.

Succinylcholine has no disadvantageous side-effects. Many times the clinically effective dose has been administered without prolonged apnea.



In conclusion this study indicates that Succinylcholine is a very safe, simple means of improving and widening the application of the technique of electroshock.

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