EXHIBIT 5

Expert Report on
Electroconvulsive Therapy

by

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Introduction

Electroconvulsive Therapy (ECT) purportedly treats mental illness by running an electric current through a patient's brain. [1] This report addresses the question of whether ECT risks brain damage in patients to whom it is administered. The medical practitioners who prescribe and administer ECT assert that it is a safe and effective treatment for certain types of mental illness, such as severe depression. [2] Yet patients often report serious degradation of their quality of life following ECT treatment. For example, "At times, patients are so neurologically impaired following ECT that they will remain prone and apathetic for days at a time, … and unable to communicate or to carry out routine self-care. [3]

And even those who practice ECT have concerns. "ECT is one of the most controversial treatments in medicine, particularly because of still unknown mechanism of action and uncertainty about cognitive side effects." [1] A large number of scientific studies and published articles over at least seven decades have failed to satisfy critics that serious brain damage is not resulting from routine ECT treatments [3, 4].

This report discusses the physics of ECT and the biology of electrical stimulation of brain tissue. It addresses the basics of electrical science as they apply to ECT and examines the related factors of cell biology to elucidate the potential risks of this controversial form of treatment. This report also looks at the science that is used to support the contention that ECT is safe.

The author is an electrical engineer with a PhD in Biomedical Engineering and fifty years of experience in scientific research and technology development. His qualifications are summarized at the end of this report.

A Brief history of ECT

The beginnings of the medical reasoning that led eventually to the widespread use of ECT are explained in a recent Scientific American article. "In the 1930's, Hungarian neuropathologist Ladislaus Meduna observed that a certain type of brain cells, called glial cells, increased greatly in tissue taken from people with epilepsy. But samples from patients with schizophrenia and depression had far fewer glial cells in the cerebral cortex than normal. … Meduna speculated that schizophrenia and depression might result from a deficiency of glial cells, so he reasoned that by inducing a seizure, he could increase their numbers and cure his patients." [5]

Based on Meduna's reasoning, a number of different methods were used to induce seizures in mental patients. [6] "Ugo Cerletti and Lucio Bini in Italy used electricity to induce a seizure by applying electrodes they had obtained from a pig slaughterhouse to the head of one of their mental patients on April 11, 1938." [5] Eventually electric shock proved to be the most reliable and least messy way to induce seizures.

Early ECT devices applied alternating current (AC) from the power lines to the patient's head. These are called "sine wave" machines because a plot of the voltage variations over time takes the smoothly varying form of the sine function used in trigonometry. With such a machine the current flow smoothly reverses itself 120 times per second. In the 1950's ECT moved toward "square wave" devices that reverse the current flow direction abruptly rather than smoothly.

The next innovation came two decades later. "In 1976, Blatchley demonstrated the effectiveness of his device that used constant current and brief pulse ECT. At this time a report from the American Psychiatric Association (APA) endorsed the use of ECT in the treatment of depression." [7] Brief pulse ECT devices deliver the current to the brain in short pulses separated by a longer period during which the current is not flowing. [8, 9] Since the same total amount of current is delivered, the treatment is simply spread out over a longer period of time. Beginning in the 1980s this type of device has largely replaced earlier devices. [10]

Brief pulse ECT machines deliver current pulses as short as one millisecond. Newer ECT machines are called "ultrabrief pulse" devices because they can deliver pulses lasting less than one millisecond. [8, 9] The newer machines are able to produce seizures using smaller doses of electricity. [8] In spite of these developments, a minority of US ECT practitioners still use sine wave stimulation. [11]

The Practice of ECT

ECT is not usually administered as just a single treatment or even as a few treatments delivered over a short period of time. Instead "maintenance ECT is continuing with ECT beyond 6 months." [1] This is done because "... studies show a high rate of relapse after discontinuation of ECT." And "... without active treatment, virtually all remitted patients relapse within 6 months of stopping ECT." [12] Thus the benefits of ECT are temporary at best. Some patients receive hundreds of ECT treatments during their lifetimes. [13]

A recent clinical review article sheds light on the current practice of ECT. The study found that "some clinicians may consider 6–10 treatments and then consider medication maintenance, while others will continue prescribing ECT only for months or even years." Also "After acute series of ECT, the ECT long-term treatment may be considered, although this practice may vary significantly between countries or even within the same country, because there is no universal consensus about its indications, duration and frequency of administration." In addition, "it is not rare in a clinical practice to see patients who are receiving maintenance ECT weekly or biweekly for an extended period of time … ." [1]

As the patient ages the ECT doses become larger. "In general, older patients, particularly elderly patients, require higher stimulus intensities than younger patients." [8] Also larger doses are required as the patient continues to receive more ECT treatments, "seizure threshold usually increases markedly during the ECT course." [8]

Side Effects of ECT

ECT can produce what are called "adverse cognitive effects" in patients who are treated. [4] Side effects of ECT include amnesia (substantial and permanent memory loss), confusion, disorientation, apathy, disinterest, headaches, nausea, slowed reaction time, and lowered intellectual function. [11, 14-18] These are side effects of treatment that impair the mental capacity of the patient. "Cognitive side effects are usually dependent on factors such as electrode

placement, electrical dosage, stimulus parameter configuration and frequency of treatment sessions." [1]

Retrograde amnesia is the inability to remember things that happened before the treatment. This type of memory loss can extend back to childhood. Anterograde amnesia is the inability to retain new memories for more than a short time. [14] Most ECT patients experience retrograde and anterograde amnesia following ECT treatment. [3, 4, 11, 15, 18-20,] "ECT patients often lose memory of part or all of their previous lives. Anterograde amnesia may last for a couple of weeks or couple of months after treatment. However, retrograde amnesia for autobiographical information is a potentially persistent cognitive side effect of ECT. (21)" [1] Also, "The loss of autobiographical memory has not been adequately investigated." [1] Further, "permanent amnesia is one of possible, frequent and serious side effects of ECT which affects at least one-third of patients." [1] In addition, "Patients should be clearly told that ECT may have serious and permanent effects on both memory ability and non-memory cognition. ... 'the ability to plan and organize and get things done'" [22]

Other side effects can be debilitating as well. "Cognitive side effects of ECT are sometimes underestimated and may last much longer after completed treatment than it is usually expected. These cognitive impairments associated with ECT may cause significant functional difficulties and prevent patients to return to work." [1]

There is even a concern that existing procedures for evaluating patients for cognitive side effects and rehabilitating them are inadequate, "Neuropsychological assessment should be a part of good clinical practice in the ECT units." And, "The lack of neuropsychological services available to ECT psychiatrists may have negative impact on identifying and assessing cognitive effects of ECT. This may also significantly delay the process of post-ECT cognitive rehabilitation." [1]

The Mechanism of Therapy

No one can explain how electric shock could reduce any of the symptoms of mental illness. "…the mechanism of therapeutic action of ECT has not yet been established." [1] And "The mode of action of electroconvulsive therapy (ECT) is unknown, although there is a burgeoning and increasingly complex literature." [60] And "The efficacy of any medical treatment depends on scientific understanding of the disorder, and how the treatment is applied. But that insight is largely lacking with ECT" [5] As mentioned above, the seizure is commonly thought to be the therapeutic agent. But ECT treatments typically use from two to six times the amount of electricity that is required simply to initiate a seizure. This suggests that whatever ECT is doing to the brain, it must be more than simply inducing a seizure.

One popular theory is that ECT works by causing the release of a neurochemical called "GABA" in an attempt to stop the seizure. "The core concept of the GABA hypothesis of ECT was that electrically induced seizures in ECT are terminated by the brain's homeostatic mechanism – an outpouring of GABA and other inhibitory neurochemicals – to terminate the seizure and prevent status epilepticus and brain damage." [60] Thus it may be the body's natural response to injury that causes temporary improvement in some ECT patients.

The effects of electric currents on the human body are well known, [23-27] and the electric current levels that ECT produces in the head are so high (approximately one ampere) that direct, possibly damaging, electrical effects on the brain are an obvious possibility.

The Basics of Electricity

In electrical science, we work with three basic quantities: voltage, current, and resistance. **Voltage** is the pressure that puts a force on charged particles (such as electrons) and causes them to move through an object. It is analogous to the pressure that causes water molecules to flow through a pipe. Applying a voltage to an object tends to pull positively charged particles in one direction while pushing negatively charged particles in the opposite direction.

Applying a voltage to an object causes a **current** to flow through it. In response to the force of an applied voltage, electrons will jump from one atom to the next. This causes a general migration of electrons through the object. This migration is the current flow that results from the applied voltage. The current is measured by the rate at which the electrons are passing through the object. It is analogous to the rate at which water is flowing through a hose. Water flow can be measured in gallons per minute. Current flow is commonly measured in amperes, or "amps." One amp is a flow rate of approximately six billion billion electrons per second.

Resistance is the amount of opposition that an object presents to current flow. In metals such as copper, the electrons are only loosely attached to the atoms. Therefore only a small applied voltage is required to produce a large current flow, and copper is said to have a low resistance. Insulating materials, such as glass, have their electrons tightly attached to their atoms. Since a large applied voltage is required to produce only a small current flow, glass has a high resistance. Resistance is measured in units of ohms. In the human body the resistance depends greatly upon the nature of the physical contact made between the body and the source of electricity.

The relationship among there three quantities is specified by **Ohm's law**. This law of physics states that the current (in amps) that will flow through an object is equal to the applied voltage (in volts) divided by that object's resistance (in ohms). The familiar formula is $I = E/R$, where E is the voltage in volts, R is the resistance in ohms, and I is the current in amps. If any two of these quantities are known, the third will be determined by Ohm's law. For example, modern ECT devices are constant current sources. That is, the operator sets the desired value of current, and the machine uses Ohm's law to adjust the voltage, as necessary, to produce that amount of current flow.

ECT Dose

The amount of electricity that is delivered to the patient's head during an ECT treatment can be specified in several ways. In the past it was common to specify the total amount of electrical **energy** that is transferred into the patient's head during one treatment. This energy is measured in "joules." One hundred joules is the amount of electrical energy that is converted into heat and light by a 100-watt light bulb every second.

More recently it has become customary to specify the dose of an ECT treatment as the "**charge**." This is the total number of electrons that are forced through the patient's head during one treatment. The charge is specified in "coulombs." One coulomb consists of approximately six billion billion electrons. It is the result of one amp of current flowing for one second.

A typical ECT dose size is about one-third of a coulomb. [8, 9, 28, 29] In one example the dose is delivered at a pulse frequency of 70 Hertz (70 positive and 70 negative pulses every second, delivered in alternation) for a period of 7.2 seconds, for a total of 1008 pulses. Each pulse is 0.3

milliseconds in duration, with 6.84 milliseconds of dead time (where the current is not flowing) between pulses. [30]

Modern ECT machines (in the USA) can deliver up to 100 joules of energy or one-half coulomb of charge (200 joules and one coulomb in Europe, Asia, and elsewhere). The pulse frequency can be set between 10 and 70 Hertz, and the pulses can be as brief as 0.3 milliseconds. The current can be set as high as 0.9 amp, and the voltage will go as high as needed (up to 460 volts) to overcome the resistance of the patient's head. [8, 29, 30] "… a constant-current device will increase output voltage (typically up to a safety limit of 400-500 V) in delivering the predetermined charge." [61]

Dose Determination

ECT device manufacturers suggest two methods for setting the ECT stimulus intensity for individual patients. These are based on recommendations of the American Psychiatric Association Task Force on ECT. [2] Both methods are based on the seizure threshold, which is the minimum stimulus intensity (electrical dose) that is required to induce an adequate seizure (convulsions lasting for 30 to 60 seconds after the shock). [2, 31-33] It is to the patient's benefit to keep the level of electrical stimulus as low as possible, "By reducing the strength of electrical stimulus, however, we may greatly reduce cognitive side effects (20)." [34]

The seizure threshold varies greatly from one patient to the next, and it increases as the patient receives more treatments. [32] "There is marked variability among patients in seizure threshold. Seizure threshold may be influenced by concurrent medications. Further, seizure threshold usually increases markedly during the ECT course." Also "seizure threshold is greater in males than females. ... In general, older patients, particularly elderly patients, require higher stimulus intensities than younger patients." And "Degree of oxygenation, dosage and type of anesthetics, concomitant psychotropic medication, quality of electrodes, site preparation, and a variety of other factors influence seizure threshold." [8] Thus determining the seizure threshold, upon which to base the treatment dose, is not simple.

One method of determining the seizure threshold is called **empirical titration**. According to the Mecta Spectrum manual, "This method, termed EMPIRICAL TITRATION, involves administration of subconvulsive intensities in the first treatment, finding the intensity level that produces an adequate seizure in that session, and in subsequent sessions administering an intensity that is a fixed amount above the seizure threshold identified in the first session." [8] The practitioner gives the new patient a series of shocks of gradually increasing intensity until a suitable seizure is induced. "… the great majority [of patients] have an adequate seizure before or following the third stimulation. However, the range in seizure threshold is great and exceptional patients may have very high thresholds. If the third stimulation does not produce a seizure, a fourth or fifth stimulation should be attempted. The final stimulation is at maximal device dosage." [8] This process is used to establish the patient's initial seizure threshold.

That patient's regular treatment dose is then set at four to six times the seizure threshold. For example, "In subsequent treatments you plan on delivering a dose that will be approximately 6 times this initial seizure threshold." And "Thus, the goal with unilateral ECT is to administer stimulation that is at least 4 times the seizure threshold, with an upper limit of 6.0 times the seizure threshold." [8] Also, "Once the seizure threshold is determined for a specific PERCENT ENERGY setting, the recommended dosing level for unilateral ECT is 4-6 times that threshold

value." [9] This calls into question the assumption that the seizure is the therapeutic phenomenon.

The second method of dose determination involves picking a stimulus intensity value off a chart, "An alternative to the titration method is to use the known predictors of seizure threshold (electrode placement, age, and gender) and preselect a dosage that on a probabilistic basis is likely to be in the appropriate range relative to seizure threshold. … This approach is termed the PRESELECTED DOSAGE METHOD." [8] Notice that this method is more of a gamble than anything precise, particularly in view of the above-mentioned wide variability of seizure threshold among patients.

But seizure threshold is not well correlated with age and gender, [8] and use of the charts and tables can lead to overdosing patients and creating more serious side effects than are warranted. According to the MECTA manual, "However, current research indicates that there is only a weak relationship between patient age and seizure threshold." And, "This circumstance means that dosing based on age will intrinsically result in the oldest patients receiving the greatest excess of electrical stimulation." Also, "In general, none of the formula-based or preselected dosage methods yet devised provide the level of accuracy that is achieved with empirical titration. Accurate determination of dosage is one of the key aspects of … minimizing side effects." In addition, "If acute cognitive side effects become excessive and clinical progress is acceptable, dosing at later treatments may be reduced." [8] Notice that cognitive side effects are both expected and tolerable.

Using the dosing tables increases the risk for the patient, "It is important to note that the treatment methods and stimulus parameter settings presented here are only suggestions." And, "Further, the suggested settings in the Titration tables and Pre-selected Dosage table are likely to be overestimates of the stimulus intensity necessary to produce adequate seizures." [8] Thus an ECT patient will likely get even more electrical stimulus than American Psychiatric Association (APA) and manufacturer guidelines call for, along with more serious cognitive side effects.

According to the ECT literature, "The goal of each ECT treatment became achieving an 'adequate' seizure, using the minimum amount of electricity at each treatment to minimize side effects." [60] In spite of these professional guidelines, approximately half of US practitioners do not adjust dosage relative to the patient's seizure threshold. [11] Some simply set the "% Dose" knob according to the patient's age. According to the Somatics Thymatron instruction manual, "Satisfactory therapeutic results can be obtained with right unilateral ECT by simply setting the PERCENT ENERGY dial to approximate the patient's age in years (e.g., 75% for a 72 year-old patient). … Once a patient obtains a satisfactory seizure with a given PERCENT ENERGY stimulus dose with unilateral ECT, we *do not* recommend administering subsequent treatments with progressively lower settings in an attempt to deliver the smallest stimulus that will still induce a seizure." [9] This technique is almost certain to set the stimulus intensity well above 6 times seizure threshold and thereby increase the severity of cognitive side effects.

ECT Device Operation

A modern ECT device is a constant-current pulse generator. That is, it automatically and continuously adjusts the voltage, as necessary, to maintain the current at a specified level. "… a constant-current [ECT] device will increase output voltage (typically up to a safety limit of 400-500 V) in delivering the predetermined charge." [61] The current is typically set at 0.9 amps. See

the example in [30] mentioned above. Thus the patient's brain is subjected to over a thousand alternating positive and negative current pulses of almost one amp each.

An ECT machine accomplishes this by applying an alternating voltage of whatever intensity is required to produce the specified 0.9 amp current. From Ohm's law we know that voltage equals current times resistance (E = IR). The resistance of the patient's head varies from one individual to the next and with the details of electrode attachment. Typical values are 1,440 ohms prior to treatment, dropping to 260 ohms during the treatment. See the example in [30]. In this case the voltage would settle to 0.9 x 260 or 234 volts during each pulse. By contrast, individual brain cells operate normally with less than one-half of a volt and a current of less than 0.001 amp. [39]

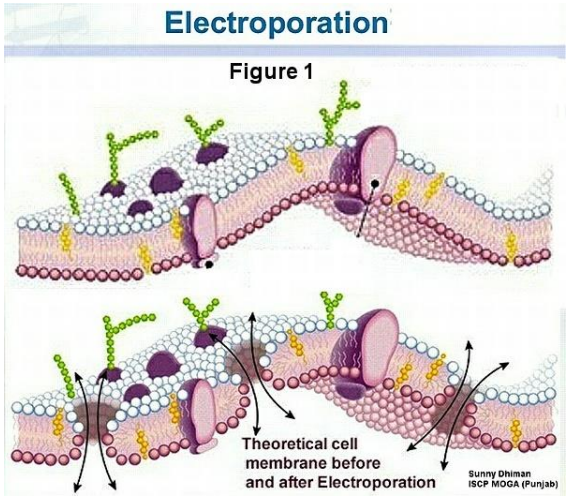
Heating in the Brain

Two things happen when an electric current, such as that from an ECT device, is caused to flow through the brain. The first is heating. The internal temperature of the human body is regulated within narrow limits to maintain the health and proper functioning of the cells. As the temperature rises, the cells can suffer dysfunction, temporary injury, permanent damage, or even cell death. [35] This is particularly true in the brain, where the electrical energy supplied by an ECT device is converted into heat, thereby raising its temperature. The larger the current, the more heat is produced. In fact, the amount of power transferred into the brain is proportional to the square of the current ($P = I^2R$). For the example that is cited in the Somatics brochure [30], this works out to 0.9 amps squared times 260 ohms or 210.6 watts during each pulse. Since the current is actually flowing only 4.2% of the time, the average power is just under nine watts. The total current is unevenly distributed throughout the brain, and some cells, particularly the larger ones, will get more heating than others. Thus brain heating is a potential source of cell injury and cell death. [23-27]

Electroporation

The second effect results from the pulsing nature of the voltage applied by ECT machines. [8, 9] During each pulse, one electrode instantly becomes positively charged, and the other electrode becomes negatively charged, establishing an electrical potential of up to 240 volts between them. This creates a sudden and intense pull on all of the charged particles inside the head. This includes the charged molecules that reside within the membrane that separates the interior of a cell from the outside environment. [36-38] Then, on the next pulse, the polarity is reversed, and all of the charged particles are instantly pulled in the opposite direction.

This process of alternately pulling and tugging on the cell membrane creates a jackhammer effect that can tear holes in a cell. This process is called "electroporation," the creation of pores (holes) in the cell membrane by electrical means. [36-41] "Electroporation involves applying electric field pulses to cells, leading to the alteration or destruction of cell membranes." [42] Electroporation is illustrated graphically in Figure 1, and Figure 2 shows a laboratory example at 60,000X magnification [from 43].



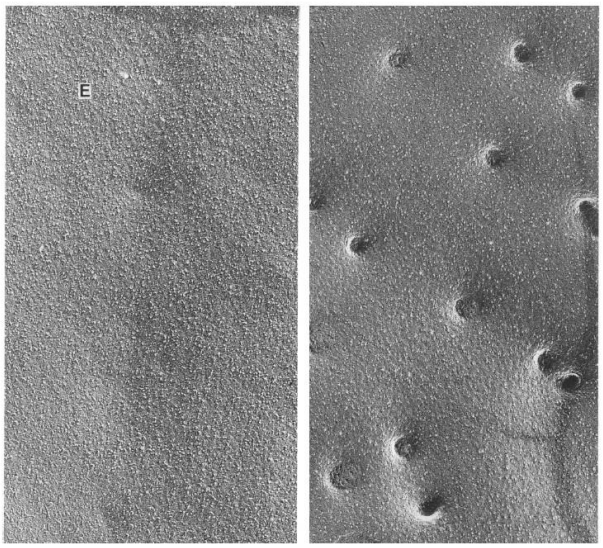


Figure 2

At low voltage levels the forces are not strong enough to damage the cell membrane. At medium voltage levels small holes are produced, but the cells can repair them before too much damage is done. Higher voltage levels, however, produce more and larger holes, the repair mechanism becomes overwhelmed, foreign substances leak into the cell, and the cell dies. [41, 42] "Irreversible electroporation (IRE) creates permanent defects in cell membranes and induces cell death." [42]

Electroporation at medium voltage levels is used in biological science to force experimental drugs inside cells for research purposes. "The electropermeabilization [using electricity to make them permeable] of biological cell membranes by the application of an external field occurs whenever an applied field exceeds a threshold value. For fields above this threshold value but less than another critical value, the pores formed in the membrane are transient or reversible." [39] Thus if the electric field is not too strong, then the cell can repair the holes before too much damage is done.

It is used at higher voltage levels in cancer therapy to kill malignant cells in the brain. [42] "This study identified N-TIRE pulse parameters that can be used to safely create circumscribed foci of brain necrosis [tissue death] while selectively preserving major vascular structures." [41]

The degree of electroporation effect on any particular cell depends on (1) the local electric field strength and (2) the size of the cell. [36, 38, 40] Red blood cells, for example are quite small and thus less likely to be seriously affected by an electric field. Brain cells, however, which can extend more than halfway across the head, are many times more vulnerable to damage by electroporation.

Further, the scientific literature gives little or no guidance regarding how ECT electric field strength is distributed throughout the head. As little as one volt across the cell membrane can open holes. "While the mechanism of electroporation is not completely understood, numerous experiments show that electroporation occurs for short pulses when the transmembrane voltage

reaches approximately 1 V. The electric field pulses causing the electroporation of cells are typically of magnitude 1-20 kV/cm and have duration of 10 μs to 10 ms." (2 – 22 mC) [39] Notice that ECT pulse durations fall in the middle of that range.

Although electroporation has been used in biological research and cancer therapy for more than a decade, there have been no published studies assessing the risk of ECT pulses causing brain cell death by this well-documented mechanism. Further, the distribution of electric field strength inside the head during ECT treatment has not been mapped. Thus it is presently impossible to assess the level of risk of this type of brain damage that ECT imposes and therefore to accurately assess the safety of ECT devices.

Voltage and Current Levels

As stated above, voltage is the pressure that causes current to flow. Resistance is the property of an object that impedes the flow of current. The electrical resistance of the human body is not easily predicted. It depends on where the two points of contact are located on the body and the size and nature of those contacts. Dry skin has a much higher resistance than wet skin. [44] The salty fluids inside the body have a relatively low resistance. The path that the current will take through the body is likewise difficult to predict. The overall current flow will be from one electrode to the other, but the path the current follows through the body will depend on the resistance of the different organs and channels that exist in the intervening tissue.

During an ECT treatment the current will not flow in a straight line from one electrode to the other, "Rather the current distributes in a manner that is inversely proportional to the resistance of the tissue compartments traversed." [61] Thus low-resistance tissue (such as brain) will receive more current than high-resistance material like bone.

Some ECT advocates have advanced the theory that, because skin offers less resistance to current flow than bone, "the majority of the current can always be expected to be shunted through the scalp," and "the relatively low resistance of the scalp and the very high resistance of the skull intervene before current reaches brain tissue." [61] However, bone is a porous matrix of canals that are filled with low-resistance materials. "Electrical resistivity of bone tissue is largely determined by its microstructure. The latter comprises a large number of pores filled with electrically conductive material – blood, lymph, nerve tissue, etc." [62] This makes the resistance of bone highly variable, "The resistivity of bone is the most variable of all the tissues in the human body, ranging from 312 ohm-cm to 84,745 ohm-cm." [63] The distribution of current flow during ECT has not been determined with any accuracy. Even if 90% of the ECT current remained outside the skull, there is still enough inside to cause a seizure, and plenty of voltage and current available to endanger brain cells.

During ECT treatment a typical value for the resistance of the head is 1,440 ohms prior to initiation, dropping to 260 ohms during treatment [30]. Modern ECT devices automatically and continuously adjust the voltage, as necessary, to maintain the current at a specified level of between one-half and one amp. [8, 9] While the voltage may be different from one patient to the next, from one treatment to the next, and may even fluctuate during one treatment, the current is the quantity that is held constant.

A current flow through the body of less than 0.01 amp (10 milliamperes) can produce a painful shock. Currents above about 10 milliamperes become dangerous. "The severity of an electrical shock is determined by the amount of current (amperes, A) and the duration of the current flow.

In medical terms, electrical shocks are usually divided into two categories. Macroshock refers to larger currents (typically more than 10 mA) flowing through a person, which can cause harm or death." [44]

Stun gun (Taser) devices are used by law enforcement to subdue suspects and by citizens for self-defense. They incapacitate a person by inducing massive muscle contractions. A stun gun can develop up to 50,000 volts in order to penetrate clothing, initiate a spark, and make contact with the body. But the amount of current that it actually forces through the victim's body is only about 0.002 amps. "The [Taser] X26 — a model commonly used by police departments — delivers a peak voltage of 1200 V to the body. Once the barbs establish a circuit, the gun generates a series of 100-microsecond pulses at a rate of 19 per second. Each pulse carries 100 microcoulombs of charge, so the average current is 1.9 milliamperes." [49] Notice that these pulse parameters are similar to those of ECT devices, (0.1 millisecond, 19 per second) but the charge delivered by a Taser (0.1 millicoulombs per pulse) is considerably less.

Cattle prods also deliver about 0.002 amps, and an electric fence can turn a cow around with only about 0.012 amps. Automotive spark plugs also operate with currents of just a few milliamperes, despite their high voltage ratings. As with Tasers, cattle prods and electric fences, once current begins to flow, the voltage drops significantly because these devices simply are not designed to deliver high currents.

The National Electric Code specifies that Ground Fault Circuit Interrupter (GFCI) circuit breakers must be used anywhere electrical outlets are located outdoors or near plumbing pipes. These are circuit breakers that sense when more current is flowing out of the main circuit than is flowing back in, such as when current is leaking through a short circuit to ground. This is a safety feature since that leakage current could be flowing through a human body. In the USA, GFCI breakers are required to shut off the circuit any time the leakage current exceeds 0.005 amps. This value of 0.005 amps was chosen as an upper limit to prevent accidental injury or death by electrocution. [45]

Slaughterhouses use a one-second electric shock to the head to "stun" animals (knock them unconscious) before slaughter. Some slaughterhouses also run the electric current through the entire body so that it stops the heart and kills the animal. The recommended current for stunning sheep is one amp, and for 200 pound pigs it is 1.25 amps [46]. Notice that one amp (about the same current that ECT uses) flowing for one second is equivalent to a one-coulomb ECT dose.

Electrocution has been used to carry out death sentences on convicted criminals. Sponges soaked in saltwater are clamped by metal electrodes to the convict's shaven head and ankles. A current as high as five amps is run through the inmate's body for several seconds. In addition to unconsciousness and cardiac arrest, this produces severe heating of the tissues. The brain is heated to between 138 and 148 degrees Fahrenheit. The bodies often show severe burns at the electrode sites and the flesh appears "cooked." The current produces violent contraction of muscles, sometimes breaking bones. [47]

So, to put this all in perspective, the amount of electric current that an ECT machine puts through a patient's head is about 200 times what is considered dangerous for ground fault leakage, approximately 100 times what Tasers, cattle prods, and electric fences use, about the same as what is used for stunning pigs, and roughly one-fifth as much as the electric chair. In addition, the amount of voltage applied to the head (up to 460 volts) is about 400 times what is required to

damage a single brain cell. Clearly this amount of electricity has the potential to cause injury to the brain.

The Science Behind ECT

ECT-induced structural brain trauma can be detected objectively by direct microscopic examination of brain tissue following treatment. Such damage is often too subtle to be detected by indirect methods. But the majority of published scientific studies seeking to evaluate ECT-induced brain damage use indirect methods such as computed tomography brain imaging, magnetic resonance imaging, proton magnetic resonance spectroscopic imaging, cerebrospinal fluid levels of markers of neuronal or glial cell degeneration, and serum levels of markers of brain tissue damage. [13] These techniques have limited resolution, do not look at individual brain cells directly, and thus can detect only relatively large changes in the brain, not the loss of individual neurons.

Regarding direct microscopic examination of the brains of ECT patients, a recent research paper says "Only 2 prior reports of postmortem gross and microscopic evaluation of brain in ECT patients have appeared in the last 3 decades," and "In summary, it seems that there have been only 3 relatively recent reports of postmortem studies of patients who received large numbers of ECT treatments, and only 2 in which modern techniques were used exclusively." [13] This means that a sensitive study looking directly at brain tissue for ECT-induced damage has been conducted only about once per decade, and then only on a single patient each time. Studying only three patients in 30 years is hopelessly inadequate to evaluate ECT-induced brain damage at the cellular level. Thus it would be improper to omit this risk from informed consent discussions with patients.

Most of the studies evaluating ECT-induced brain damage have been conducted by researchers who practice ECT themselves. Thus they have a vested professional or financial interest in the outcome of the study. They often state their preconception that ECT is safe and effective at the outset in their publications. Since these studies are seldom done under the rigorous scientific conditions of a clinical trial, the influence of investigator bias in the interpretation of experimental data cannot be ruled out.

ECT and the FDA

The United States Food and Drug Administration (FDA) was given authority to regulate medical devices in 1976. [48] ECT devices were already in use by then, so they were automatically approved ("grandfathered in") without any testing for safety or effectiveness. In response to public pressure to ban ECT, the FDA has held several hearings over the years. Each time, after hearing horror stories from ECT patients, they continued to allow ECT devices to be sold without requiring any further testing by the device manufacturers.

Normally when an FDA-approved device is modified it must be re-tested before the new design can be sold. The exception comes when the new device is considered to be "substantially equivalent" to the older model. ECT's advocates acknowledge that earlier machines did cause brain damage and serious side effects, but they claim the newer brief and ultrabrief pulse machines eliminate that problem. Yet they simultaneously argue to the FDA that the newer machines do not require testing because they are "substantially equivalent" to the older ones. In other words, they are different from, but yet they are the same as, other devices that have not been tested either. Remarkably, the FDA has accepted this pair of contradictory arguments.

The FDA normally sets a high standard for approving drugs and medical devices for public use. They require stringent clinical trials with double-blind experiments, large sample sizes, accurate statistics, and thoughtful interpretation of results. Regarding ECT, however, they are much quicker to conclude, without such evidence, that the practice is safe and effective. They tend to discount the testimony of ECT patients claiming harm as being "anecdotal" and thus unscientific. Instead they rely on the opinion of psychiatry experts where timely scientific evidence is unavailable or incomplete.

Device Classification

Under the Food, Drug, and Cosmetic Act, the U.S. Food and Drug Administration recognizes three classes of medical devices, based on the level of control necessary to assure safety and effectiveness. [48]

For years the FDA placed ECT devices in Class III ("potential unreasonable risk of illness or injury"), along with automated cardiac defibrillators, for example. But in 2018 they reclassified ECT devices for the treatment of catatonia, major depressive disorder, and bipolar disorder from Class III (higher risk) to Class II (moderate risk). [51, 59] Class II includes less risky things like powered wheelchairs, acupuncture needles, and condoms.

This reclassification will permit greatly expanded use of ECT. Since the FDA does not regulate psychiatry or medicine, practitioners can now administer electroshock more widely and for less severe conditions than the FDA has cleared it to treat. Further, the manufacturers have never been required to conduct clinical trials to evaluate the risk of injury.

The Economics of ECT

The cost of ECT treatment is high. It is used on over 100,000 people each year in the USA. [5] "With 5 to 15 treatments per initial course and 10 to 20 maintenance treatments per year, the annual cost of ECT can exceed $10,000." [52] When hospital expenses are added the cost is even higher. "The cost of ECT runs upwards from $35,000 per series. Patients generally receive 6 treatments during an inpatient stay at a hospital and get up to seven follow up ECTs on an outpatient basis. Generally patients may receive up to thirty treatments in a year. ECT treatments cost $800-$1000 per treatment plus hospital stay ($600 - $800 per day) which is generally a series of 8-12 and 25-30 days in a hospital." And "It is estimated at being a $2-3 billion dollar a year industry (53)." [54]

ECT provides a significant source of income for psychiatrists as well as revenue for hospitals. "The attending psychiatrist may charge $300 and up for a session of ECT and may easily perform five to six ECT treatments within one hour ($1,800/hour). … ECT appears to be an important moneymaker for both hospital and psychiatrists in a time when costs are high and reimbursements are scarce." [54]

Thus this is a multi-billion-dollar business in the United States alone. Under the FDA's recent reclassification of ECT devices, that business will boom.

Summary - ECT and Brain Damage

"ECT is one of the most controversial treatments in medicine, particularly because of still unknown mechanism of action and uncertainty about cognitive side effects." [1]

ECT attempts to treat mental disorders by using a high voltage to send a large electric current through the brain, inducing a seizure that lasts an additional 30 to 60 seconds. Based on research reports, it gives only temporary results in only a percentage of patients treated, while still requiring maintenance on psychiatric drugs and/or additional ECT treatments. [12] Its practitioners admit to moderate side effects, [34, 50] but some patients complain of much more devastating damage to their lives [3].

No one can explain how or why ECT "works." The scientific literature fails to establish a mechanism of therapy or to support the belief that the seizures produced by ECT are therapeutic. Further, the amount of electricity that is used in practice is routinely up to six times what is required to produce a seizure. [8, 9] The existing research also fails to show that cell damage and cell death are not still occurring, even with modern ECT equipment and practice.

ECT uses electric current levels approximately one hundred times what is considered safe in the human body and at very dangerous voltage levels. In so doing it risks brain cell damage from both heating and electroporation. Modern Brief-Pulse and Ultrabrief Pulse ECT devices are much more likely to cause electroporation than those used in the past. Adequate scientific studies to fully assess the risk of ECT-induced brain damage at the cellular level have not been done. In spite of all this, instead of requiring testing of these devices, the FDA is now allowing them to be used much more widely than ever before. [51, 59]

In summary, ECT has the potential to injure or kill brain cells by at least two different electrical mechanisms, heating and electroporation. The scientific literature has demonstrated brain damage in earlier times, and recent studies using high magnet-strength MRI show ECT-induced changes in the sizes of certain brain structures [55-58]. Little is known about whether damage on a cellular level is continuing to occur with modern ECT devices and practice. Further, studies to evaluate the risk of electroporation by ECT have not been reported. Despite its widespread use, ECT exposes patients to risks of brain damage that have not been thoroughly evaluated. The opinion of "authorities in the field" is being substituted for scientific fact.

The Author's Qualifications

I have Bachelor and Master's degrees in electrical engineering and a Ph.D. in Biomedical Engineering. The latter involves application of engineering techniques to problems in medicine and biology. My entire professional career has been dedicated to scientific research and technology development.

With over 45 years of experience, I hold image analysis and image processing patents and have served on various university and government advisory committees. I have served on the faculty at Caltech, on advisory committees for the College of Engineering and the Department of Electrical and Computer Engineering, and as an Adjunct Professor of Biomedical Engineering at The University of Texas, and as a Research Fellow at both USC and UCLA. I have also been a member of the Scientific Working Group on Imaging Technology for the Federal Bureau of Investigation.

I was a Senior Scientist at NASA's Jet Propulsion Laboratory for 15 years, and I was subsequently called in to assist NASA in their investigations of both the Space Shuttle Challenger and Columbia disasters. In 1994, I was inducted into the United States Space Foundation's Space Technology Hall of Fame, and I am a Fellow of the American Institute of Medical and Biological Engineering.

I have also served as a technical expert in legal cases, including more than thirty patent infringement cases. I have published three college-level textbooks, including the seminal textbook Digital Image Processing (1979 and 1996), which has been translated into Japanese and Chinese. I have also published more than 60 articles in scientific journals.

I have reviewed the scientific literature relating to the effects of electric fields and electric currents on human tissue. In addition, I have reviewed the body of literature concerning the history of, and the past and current practice of ECT, and the literature relating to brain trauma resulting from electric shock. The latter includes reports of postmortem microscopic studies of brain tissue from ECT patients and other studies of brain damage caused by ECT.

The opinions expressed in this report are stated to a reasonable degree of engineering certainty.

Executed this 20th day of April 2021 at League City, Texas.

Kenneth R Castleman

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Kenneth R. Castleman

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APPENDIX A

Kenneth R. Castleman, Ph.D.

Expertise

- Digital Image Processing
- Imaging and Video Hardware
- Digital Image and Video Compression
- Pattern Recognition
- Image Enhancement
- Biometric Image Recognition
- Industrial and 3-D Imaging
- Medical Imaging

Professional Summary

Dr. Kenneth R. Castleman is the noted author of the seminal textbook ***Digital Image Processing*** (1979 and 1996) and co-editor of ***Microscope Image Processing*** (2008). With over 45 years of experience, Dr. Castleman holds image analysis and image processing patents and has served on various university and government advisory committees.

Dr. Castleman has authored or co-authored more than 60 papers on digital image processing. In 1994, he was inducted into the United States Space Foundation's Space Technology Hall of Fame. He served as Visiting Committee Chairman for the Department of Electrical and Computer Engineering and served as an Adjunct Professor of Biomedical Engineering, both at the University of Texas. He was a member of the Scientific Working Group on Imaging Technology for the Federal Bureau of Investigation. Dr. Castleman assisted NASA in the investigations of the Space Shuttle Challenger and Columbia disasters and has served as a technical expert in legal cases ranging from the JFK assassination to bank robberies and numerous patent cases.

In recent years, Dr. Castleman forged ADIR into an industry leader in digital image processing research and development. Under his leadership, PSI and ADIR developed and commercialized many innovative image processing technologies. Dr. Castleman is now retired from full-time employment but still consults with industry and on legal cases.

Dr. Castleman has expert witness litigation experience in thirty different patent cases dating back to 1982. This includes more than twenty-five days of deposition and twelve days of courtroom testimony in Federal court and before the International Trade Commission.

Employment History

From: 2000 **The University of Texas at Austin**
To: 2010 Austin, Texas
Position: *Adjunct Professor of Biomedical Engineering*

From: 2000 **Advanced Digital Imaging Research, LLC**
To: 2007 League City, Texas
Position: *President*
ADIR, a subsidiary of Iris International, was an industry leader in digital image processing research and development. PSI and ADIR developed and deployed many innovative image processing technologies under government funding.

Kenneth R. Castleman, Ph.D.

From: 1991 **Perceptive Scientific Instruments, Inc.**
To: 2000 Houston, Texas
Position: *Director of Research & Development*

- 1998 - 2001: Principal Investigator, NIH SBIR Grant: "Wavelet-Based Automated Chromosome Identification."
- 1993 - 1998: Principal Investigator, NASA SBIR Contract: "Automated Chromosome Breakage Detection."
- 1994 - 1998: Principal Investigator, NIH SBIR Grant: "Automation in Prenatal Screening."
- 1993 - 1996: Principal Investigator, NIH SBIR Grant: "Automation in Leukemia Cytogenetics."
- 1995 - 1999: Principal Investigator, NIH SBIR Grant: "Eigenanalysis in Chromosome Image Processing."

In July 2000 the product line and manufacturing facilities were sold, and PSII's research department, headed by Dr. Castleman, then became an independent research organization named **Advanced Digital Imaging Research**.

From: 1985 **Perceptive Systems, Inc.**
To: 1991 Houston, TX
Position: *Chairman & CEO*
Co-founded Perceptive Systems, Inc (PSI) whose business was to commercialize digital imaging technology. PSI designed and built workstations for cytogenetics automation. In 1991 PSI was reorganized as **Perceptive Scientific Instruments, Inc.**

From: 1970 **NASA Jet Propulsion Laboratory**
To: 1985 Pasadena, CA
Position: *Senior Scientist*
Projects focused on computer processing of images from space and the adaptation of image processing techniques to medical applications.

From: 1983 **University of California Los Angeles**
To: 1985 Los Angeles, CA
Position: *Research Fellow*
Automated analysis of Pap smear specimens

From: 1981 **University of Southern California**
To: 1982 Los Angeles, CA
Position: *Research Fellow*
Automated analysis of coronary angiogram images.

From: 1975 **California Institute of Technology**
To: 1977 Pasadena, CA
Position: *Lecturer*
Taught courses on “Digital Image Processing”.

Kenneth R. Castleman, Ph.D.

From:	1965	**The University of Texas at Austin**
To:	1969	Austin, TX
	Position:	*1967-1969: Research Assistant*
		1965-1966: Teaching Assistant

Patents

Patent Number	Date Issued	Title
7,236,623	06/26/2007	Analyte recognition for urinalysis diagnostic system
4,309,691	01/05/1982	Step-Oriented Pipeline Data Processing System
4,210,419	07/01/1980	Automated Quantitative Muscle Biopsy Analysis System
4,122,518	10/24/1978	Automated Clinical System for Chromosome Analysis

Education

Year	College/University	Degree
1970	University of Texas at Austin	Ph.D., Electrical Engineering*
1967	University of Texas at Austin	MS, Electrical Engineering
1965	University of Texas at Austin	BS, Electrical Engineering

* Thesis topic: Evoked Potential Analysis in the Rabbit Visual System (Application of digital signal processing techniques to biomedical engineering problems.)

Publications (within the past 10 years)

- None

Honors

2005-2010	Engineering Advisory Board, College of Engineering, The University of Texas at Austin.
2002- 2010	External Advisory Committee, Department of Biomedical Engineering, The University of Texas at Austin
2004 – 2007	Microscopic Imaging Study Section, National Institutes of Health, U. S. Dept. of Health and Human Services
2002	College of Fellows, American Institute for Medical and Biological Engineering
1999-2002	External Advisory Committee, Integrative Graduate Education & Research Training Program, The University of Texas at Austin
1997-2002	External Advisory Committee, Department of Electrical & Computer Engineering, The University of Texas at Austin
1996-2010	Scientific Working Group on Imaging Technology, Federal Bureau of Investigation
1994	Space Technology Hall of Fame, United States Space Foundation

Industrial Consulting Experience

Client: Visual Intelligence, Inc. Houston, Texas.
Client manufactures and sells digital camera systems for use in aerial photography.
Dates: July, 2006 to present.
I develop image processing algorithms to correct radiometric and geometric distortion in images.

Client: Iris International, Chatsworth, California.
Client manufactures and sells digital microscope systems for use in clinical medicine.
Dates: July 2007 through January 2009, May through August, 2011.
After I retired from a subsidiary of Iris in April 2007, I consulted with the company on image processing and pattern recognition of cell images.

Client: Cytyc Corporation, Marlborough, Massachusetts
Client manufactures and sells digital microscope systems for use in clinical medicine.
Dates: December 2006 through October 2007.
I consulted with the company on pattern recognition of cell images.

Litigation Experience (previous 4 years)

39. Law Firm: Baum Hedlund Aristei & Goldman P.C. (on behalf of Plaintiffs)
Case: 2:17-cv-06686 RGK-PJW
Parties: Himes; Scurrah; and Benjamin, Plaintiffs, v. Somatics, LLC, Defendant.
Claim: Violation of FDA regulations.
Technology: Electroconvulsive Therapy.
Dates: March 2021 to present.
Status: Plaintiffs reinstated. I expect to submit an expert report and testify at trial.

38. Client: United States Patent and Trademark Office
Case: Federal District Court, Washington, DC. (Two cases)
Parties: Gilbert Hyatt v. Director, USPTO
Claim: Plaintiff alleges failure to issue a patent for patentable subject matter.
Technology: A real-time digital video processing system.
Dates: February 2021 to Present. Ongoing.
Status: I expect to submit expert reports in 2021.

37. Law Firm: Winston and Strawn
Case: 1:14-md-02542-VSB
Parties: Treehouse Foods, Inc. et.al. v. Keurig Green Mountain, Inc.
Claim: Anti-trust violation.
Technology: Single serve coffee brewers
Dates: July 2020 to present. Ongoing.
Status: I have submitted opening and reply expert reports and have been deposed.

36. Law Firm: Dan Johnson Law Group
Case: 3:18-cv-06181-JD
Parties: Yu and Zhang v. Apple
Claim: Patent infringement.
Technology: Smart phones with multiple cameras
Dates: Nov. 2018 to Jan. 2021.

35. Law Firm: DK Law Group, LLP (on behalf of Plaintiffs)
Case: 2:17-cv-06686 RGK-PJW
Parties: Jose Riera & Deborah Chase, Plaintiffs, v. Somatics, LLC, Defendant.
Claim: Violation of FDA regulations.
Technology: Electroconvulsive Therapy.
Dates: July – Sept. 2018.
Status: I submitted a declaration and an expert report and was deposed. The case settled.

34. Law Firm: Mintz, Levin, Cohn, Ferris, Glovsky and Popeo. (on behalf of Defendant)
Case No. 17-cv-4011 (E.D. NY) and three associated IPRs.
Parties: Canon Inc., Plaintiff v. Avigilon Corp, Defendant.
Claim: Plaintiff alleged patent infringement.
Technology: Video image analysis for an intelligent security camera.
Dates: Sept. – Oct. 2017. I assisted attorneys with two IPRs.

For more information please contact:

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