How long would a single session of maximum settings electroconvulsive therapy (ECT) power a 60W lightbulb?

To the editor:

How much electricity does electroconvulsive therapy (ECT) deliver to the brain? Here we use a 60W lightbulb as a common reference for the actual amount of electricity that maximum parameter settings ECT session deposits in the brain (as this gets reflected in a utility bill we pay each month!). Notably, this paper should not be used for safety or dosage considerations, which should only be determined by a trained ECT provider. Even small amounts of electricity applied in the wrong way can be damaging.

How long would a single session of maximum settings ECT power a 60W lightbulb?

Three variables influence how long ECT would power a 60W lightbulb: Voltage (in Volts, V), current (in amperes, A), and duration (in seconds, s). These values are multiplied then divided by 60W (**See Formula 1**):

Time ECT Would Power a 60W Lightbulb

$$= \frac{\text{Voltage} * \text{Current} * \text{Duration}}{60W}$$

Some have used **Formula 1** to estimate that one session of ECT would power a 60W lightbulb for 8.4s [1]. However, this calculation is wrong. The 8.4s calculation does not adequately account for the transcranial nature of ECT by only estimating the voltage and current at the scalp. In addition, the duration value overestimates the actual on-time of ECT stimulation as it does not account for interstimulus intervals when no stimulation is delivered.

Here we calculate more accurate values for the maximum voltage, current, and duration that ECT delivers by accounting for the resistance factors of skin, skull thickness, and cerebrospinal fluid shunting as well as the interstimulus interval. We then use **Formulas 1 and 2** to accurately compute the amount of time a single session of maximum settings ECT would power a 60W lightbulb.

Maximum ECT stimulation parameters

For our calculations, we used the following maximum ECT parameter settings: Pulse width = 0.0005s, frequency = 90Hz, waveform = biphasic, treatment duration = 8s, and current = 0.8A. Notably, our total charge of 576mC is larger than the 504mC previously estimated [1].

Maximum voltage calculation

Taking resistance factors into consideration, the best estimates for the maximum Electric-Field from ECT at the cortex is 2.5V/cm using a computer model [2] or 1.4V/cm from intracranial measurements in cadavers [3]. The distance value is the length between cortical surfaces underneath the electrodes along a straight line (12.8cm in the Montreal Neurological Institute (MNI)-152 template brain). Thus, the voltage at the cortex is 2.5V/cm * 12.8cm = **32.0V.**

Maximum current calculation

Likewise, the scalp, skull, and CSF shunt away much of the ECT current and thus the estimated percentage of current induced in the brain compared to the current experienced at the scalp is between 23 and 35% [4]. Taking the upper end of this range (35% or 0.35), the current delivered to the cortex is: 0.35 * 0.8A = **0.28A.**

Maximum duration calculation

While ECT delivers a maximum of 8 seconds of stimulation in each session, the electricity is not continuous. The off-time (interstimulus interval) between actual pulses is much longer than is the on-time of the ECT pulses. Therefore, to calculate the on-time, we multiplied the pulse width, frequency, waveform, and treatment duration to exclude the interstimulus intervals using the following equation: On-time = 0.0005s (Pulse Width) * 90Hz (Frequency) * 2 (Biphasic Waveform) * 8s (Maximum Treatment Duration) = **0.72**. Thus, an 8 second Maximum Treatment Duration is really only **0.72s** of current delivered.

Amount of time that a single session of maximum settings ECT would power a 60W lightbulb

Plugging our values into **Formula 1**, we calculate that **one session of maximum settings ECT would in fact power a 60W lightbulb for a mere 0.108s** (**See Formula 2**):

$$\text{Time ECT Would Power a 60W Lightbulb} = \frac{32V * 0.28A * 0.72s}{60W}$$

$$= 0.108s$$

The previous 8.4s estimate [1] is over 78 times too long, even with a higher total charge in this study (576mC compared to 504mC).

Safety considerations

It is important to acknowledge that we have simplified several concepts. We used a 60W lightbulb to convey the amount of electricity that ECT deposits in the brain without respect to many variables that can change the safety of ECT. For instance, the electrode location, size, and material can meaningfully alter ECT safety.

It is difficult to determine the exact dosage of ECT in humans that would cause tissue damage, particularly due to the extracranial application of ECT stimulation. Here we give a best estimate for how the charge density (in $\mu C/cm^2$) from maximum settings ECT in humans compares to tissue damage thresholds established from intracranial stimulation in animals [5,6].

Tissue damage thresholds

A widely accepted tissue damage threshold for intracranial stimulation is a charge density of $30\mu C/cm^2$ [5]. Nevertheless, McCreery and colleagues (1990) measured that intracranial charge densities of $12\mu C/cm^2$ can cause tissue damage [7]. We can determine how the charge density from our calculations above compare to McCreery et al.'s limit by multiplying electric field, tissue conductivity, and biphasic pulse width (See **Formula 3**):

ECT Charge Density
$= $ Electric Field $*$ Tissue Conductivity $*$ Biphasic Pulse Width

ECT charge density calculation

We plugged the following maximum settings ECT parameters discussed above into **Formula 3** to determine the ECT charge density: Electric-field $= 2.5V/cm$ [2], tissue conductivity for gray matter $= 0.276$ Siemens (S)/m, or $0.276A/(V*m)$ [8], and biphasic pulse width $= 0.0010s$ ($0.0005s$ (pulse width) $*$ 2 (biphasic waveform) $= 0.0010s$). After converting meters (m) to centimeters (cm) and Coulombs (C, or A*s) to micro-Coulombs (μC), the charge density for maximum settings ECT is **6.90$\mu C/cm^2$** (See **Formula 4**):

$$ECT\ Charge\ Density = \frac{2.5V}{cm}*\frac{0.276A}{V*m}*0.0010s*\frac{1m}{100cm}*\frac{10^6\mu C}{1C}$$
$$= 6.90\mu C/cm^2$$

Therefore, maximum settings ECT produces a charge density that is more than 40% lower than the most stringent tissue damage thresholds [7] and over 700% below commonly accepted values [5]. The charge density of maximum settings ECT is likely even further below these thresholds since ECT is applied extracranially and McCreery et al.'s (1990) limits were determined intracranially with electrodes directly on the cortex. Additionally, many patients receive ECT treatments that are below maximum settings.

Conclusions

Reasoning from simple first principles reveals that the maximum amount of electricity used in ECT does not cause tissue damage and would power a 60W lightbulb for only 0.108 seconds.

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Conflicts of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there was no financial support for this work that could have influenced its outcome.

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