

A reliable method to reduce electrode impedances during electroconvulsive therapy

Tomoya Shimano,^{1,2} Enami Sawayama,¹ Satoru Oishi,¹ Takashi Natsuyama,¹
Takeya Takizawa,¹ Masanori Saito,¹ Katsutoshi Tanaka,³ Hitoshi Miyaoka¹

¹ Department of Psychiatry, Kitasato University School of Medicine

² Department of Psychiatry, Kitasato University Graduate School of Medical Sciences

³ Department of Occupational Mental Health, Kitasato University Graduate School of Medical Sciences

Background: To assure good contact between the electroconvulsive therapy (ECT) electrode and the scalp, pretreatment with conventional conductive skin preparations (PRE TAC) is recommended. To date, no quantitative study regarding the utility of preparation agents has been performed.

Objective: This study aimed to compare the effectiveness and safety of the use of defibrillator gel (Gelaid) with those of PRE TAC for electrode impedance during ECT.

Methods: Ten inpatients with depression who were eligible to receive ECT were included. In the first six successive ECT sessions, the skin preparation agent was alternated between Gelaid and PRE TAC. Static and dynamic impedances and the number of reapplications were recorded. The post-session appearance of the skin under the ECT electrode was examined.

Results: The static impedance was related to the agents used. Additionally, the dynamic impedance tended to be associated with the agents used. The number of times required for attachment was related to the agents used, the age, and number of treatments. No posttreatment adverse events, including changes in the skin and hair at the sites where ECT electrodes were applied, were observed for either agents.

Conclusions: Defibrillator gel may be used to reduce the electrode impedance for ECT.

Key words: electroconvulsive therapy, impedance, defibrillator gel, depression, electric burn

Introduction

The treatment of mental disorders using electroconvulsive therapy (ECT) was developed in Italy by Cerletti and Bini and first applied to a human patient in 1938.¹ Since then, ECT has been acknowledged as one of the most effective treatments for various types of mental disorders, e.g., mood disorders and catatonia.²⁻⁵

Upon its inception, ECT was performed without anesthesia, causing adverse events such as patient fear, anxiety, muscle pain, and fractures.^{6,7} Many improvements have been made to reduce the occurrence of these adverse events, including the use of intravenous anesthesia and muscle relaxants, the adaptation of direct current pulse waves, and bilateral or unilateral electrode placement. The effectiveness and safety of ECT have thus been greatly improved. Outpatient ECT is now

available in many clinics, in addition to the provision of traditional inpatient ECT.

There is still room for improvement in the ECT electrode placement techniques. High skin/electrode resistance (static impedance), due to poor contact of the ECT electrode with the scalp and involvement of hair, can cause not only scalp burns but also cerebral unifocal stimulation.⁸⁻¹² To assure good contact between the ECT electrode and the scalp, pretreatment with conventional conductive skin preparations (PRE TAC [Pharmaceutical Innovations, Newark, NJ, USA]) is recommended.¹³ In many cases, however, PRE TAC does not adequately reduce the impedances; therefore, trials to develop more appropriate agents and techniques using electrode pads and their application are required.¹⁴ Although other preparation agents, such as saline and conductive gel, are also recommended,^{1,6,15} to date, to our knowledge, no

Received 6 October 2020, accepted 29 October 2020

Correspondence to: Tomoya Shimano, Department of Psychiatry, Kitasato University School of Medicine

1-15-1 Kitasato, Minami-ku, Sagami-hara, Kanagawa 252-0374, Japan

E-mail: dm17013@st.kitasato-u.ac.jp

quantitative study regarding the utility and efficacy of such agents has been performed. Therefore, we compared the effectiveness and safety of defibrillator gel (Gelaïd Z-101BA, Nihon Kohden) with those of PRE TAC for the prevention of skin injuries during ECT.

Materials and Methods

Participants

Ten female inpatients (age 63.9 [\pm 10.9] years) with depression eligible to receive ECT were included in this study. No one dropped out of the study after enrollment. Participants were excluded from the study if they wished to withdraw or their legal representatives wished to withdraw them from the study before or during the study, or if they had a new or previous history of PRE TAC or Gelaïd allergies.

Study design

This comparative study, conducted from November 2017 through February 2019, evaluated agents used to reduce skin resistance to disposable ECT electrode pads (Thymapads; Somatic, LLC, Lake Bluff, IL, USA) at Kitasato University East Hospital in Kanagawa. The ECT device used was the Thymatron System IV (Somatic).

Selection of agents

We performed a literature search to identify alternatives to conventional conductive agents and found several candidates.^{1,16} We compared three Nihon Kohden conductive gels for conductivity and skin-irritability. Gelaïd was used as a defibrillator gel, Gel Sonic was used as an ultrasound gel, and cardioCream was used as an electrocardiogram gel. Table 1 shows the conductivity data for each agent. Noteworthy, data on PRE TAC were not provided by the manufacturer. As an alternative candidate, Gelaïd was selected due to its conductivity and safety. Gelaïd is designed to be used safely in defibrillation with higher energy output than that in pulse

wave therapy devices. Therefore, we decided to conduct this study using PRE TAC and Gelaïd.

Procedures

Bilateral ECT was performed in all the cases. In the first successive 6 sessions of overall ECT, the ECT electrodes were attached using PRE TAC in odd sessions and Gelaïd in even sessions (data were obtained at least 3 times for each session). If an ECT electrode peeled off or the skin/electrode static impedance was high (at least 2,000 Ω when it had been attached using each method, the same agent was used until a lower value was acquired. With the exception of the step in which the ECT electrodes were mounted, the procedures performed were identical in both groups. Each ECT electrode was held in place with a foam handle applicator during static impedance measurements and energization.

1) Attaching the ECT electrode using PRE TAC

- Using cotton moistened with saline, clean the skin at the site where the ECT electrode is to be attached, slightly wider than the ECT electrode, and then dry the skin.
- Apply 1–2 drops of PRE TAC to the skin and dab with the fingertips to dry.
- After confirming that the pretreated skin is completely dry, press the ECT electrode flat against the skin.

2) Attaching the ECT electrode using Gelaïd

- Apply a small amount of Gelaïd to the skin where the ECT electrode will be attached, slightly wider than the ECT electrode pad.
- Press the ECT electrode flat against the area where the skin was pretreated.

Endpoints

The primary endpoint was the static impedance. The secondary endpoint was the dynamic impedance. And the tertiary endpoint was the number of times required to attach the ECT electrode and reduce the static impedance to less than 2,000 Ω . Furthermore, the presence of side effects (e.g., skin changes after treatment observed on a postprocedural examination) was rated by a psychiatrist who did not attend the ECT treatment sessions and was independent of the therapists.

Statistical analyses

We collected a total of 6 data points per patient, i.e., 3 times for each drug. After adjusting the obtained data by age and the number of treatments, we compared the static impedance, the dynamic impedance, and the number of times required to attach the ECT electrode using the generalized estimating equation (GEE) between the PRE

Table 1. Differences between the resistivity of Gelaïd and other agents

Brand name	Use	Resistivity ($\Omega \cdot \text{cm}$)
Gelaïd	Defibrillator gel	18
Gel Sonic	Ultrasound gel	2,800
cardioCream	Electrocardiogram gel	940
Saline		70

TAC and Gelaid groups. P-values of <0.05 were considered statistically significant. SPSS ver 23.0 (IBM SPSS, 2015) was used for all statistical analyses.

Ethics statement

This study was conducted in accordance with the ethical standards detailed in the Declaration of Helsinki. This study was approved by Kitasato University Medical Ethics Organization (C17-103) and registered with the University Hospital's medical information network clinical trial registry (UMIN000029134). Written informed consent was obtained from the participants or their legal representatives.

Results

Participants' characteristics

All the participants were women (age 63.9 [\pm 10.9]

years). Because we performed at least 6 ECT procedures on each and all of the participants, data for 30 PRE TAC or Gelaid readings were gathered. Table 2 shows the mean and difference for agents of the static impedance, dynamic impedance, and the number of times required to attach the ECT electrode. In the static impedance, the mean value of PRE TAC was 1566.35 [95% CI; 1451.07 – 1681.64] and the mean value of Gelaid was 1283.31 [95% CI; 1168.03 – 1398.60], with a difference of 283.04 [95% CI; 116.39 – 449.69]. In the dynamic impedance, the mean value of PRE TAC was 243.17 [95% CI; 233.01 – 253.32], and the mean value of Gelaid was 230.83 [95% CI; 220.68 – 240.99], with a difference of 12.33 [95% CI; -2.35 – 27.02]. For the number of times required for successful attachment (times), the mean for PRE TAC was 1.80 [95% CI; 1.55 – 2.05], and the mean for Gelaid was 1.10 [95% CI; 0.85 – 1.35], with a difference of 0.7 [95% CI; 0.34 – 1.05]. There were no posttreatment side

Table 2. PRE TAC and Gelaid skin resistance and the number of times required for attachment

	Mean (95% CI)	Difference (95% CI)
Static impedance (Ω)		
PRE TAC	1,566.35 (1,451.07 – 1,681.64)	283.04 (116.39 – 449.69)
Gelaid	1,283.31 (1,168.03 – 1,398.60)	
Dynamic impedance (Ω)		
PRE TAC	243.17 (233.01 – 253.32)	12.33 (-2.35 – 27.02)
Gelaid	230.83 (220.68 – 240.99)	
Times required for attachment (times)		
PRE TAC	1.80 (1.55 – 2.05)	0.7 (0.34 – 1.05)
Gelaid	1.10 (0.85 – 1.35)	

95% CI, 95% Wald confidence interval

Table 3. GEE (generalized estimating equation) with PRE TAC and Gelaid

Explanatory	Objective and confounding	B	SE	95% CI	P value
Static impedance	Agents used	283.04	85.03	116.39 – 449.69	8.7×10^{-4}
	Age	3.42	3.75	-3.93 – 10.77	0.362
	Number of treatments	13.38	24.89	-35.42 – 62.17	0.591
Dynamic impedance	Agents used	12.33	7.49	-2.35 – 27.02	0.100
	Age	-0.09	0.33	-0.73 – 0.56	0.794
	Number of treatments	-1.00	2.19	-5.30 – 3.30	0.648
Times required for attachment	Agents used	0.70	0.18	0.34 – 1.05	1.4×10^{-4}
	Age	0.02	0.01	4.5×10^{-4} – 0.03	0.044
	Number of treatments	-0.14	0.05	-0.24 – -0.03	0.010

B; unstandardized partial regression coefficient, SE; standard error
Significant P values ($P < 0.05$) in boldface

effects, or adverse events, including changes in the skin and hair at the sites where ECT electrodes were applied, observed for either conductive agent.

Factors associated with resistivity

The results of the GEE are shown in Table 3. The static impedance was related to the agents used (unstandardized partial regression coefficient (B) = 283.04, 95% CI; 116.39–449.69, $P = 8.7 \times 10^{-4}$). Likewise, the dynamic impedance tended to be associated with the agents used (B = 12.33, 95% CI; -2.35–27.02, $P = 0.0997$). The number of times required for attachment was also related to the agents used (B = 0.70, 95% CI; 0.34–1.05, $P = 1.4 \times 10^{-4}$), the age (B = 0.02, 95% CI; 4.5×10^{-4} –0.03, $P = 0.044$), and number of treatments (B = -0.14, 95% CI; -0.24–-0.03, $P = 0.010$).

Discussion

Maintaining proper attachment between the ECT electrode and the skin is essential for effective and safe ECT procedures. Static impedance is measured as 350–2,000 Ω under the proper setting.¹⁷ It should be adjusted to less than 1,500 Ω to further improve the quality of stimulation.¹ If the impedance measured immediately before applying the pulse wave is inadequate, the stimulus pads must be reattached under general anesthesia. For secure attachment and effective treatment, the following 3 factors should be considered.

Increased adhesion of ECT electrode pads

Skin preparation agents should be easily and efficiently applicable. Several agents are recommended in the guidelines, by manufacturers, and providers.^{1,6,15} Among those, Thymatron System IV manufactures specify using PRE TAC.¹³ PRE TAC contains two ingredients: aluminum chlorohydrate to remove oil components from the skin to increase the adhesion of the ECT electrode pad, and conductive salts to increase the conductivity by remaining on the skin after the alcohol solvent has dried.¹⁶ Gelaid, electrically conductive wet gel used for defibrillation, contains large amounts of water and conductive salts that remain between the ECT electrode pad and patient's skin during ECT procedures. Both PRE TAC and Gelaid are used to assure good and uniform skin conductivity. Applying the former, however, requires abrasive skin procedures to partially remove the stratum corneum and dried alcohol solvent at the site of the application. Conversely, the use of Gelaid simply requires a uniform application to the ECT electrode pad mounting site to confirm good contact without any

additional procedures. The convenience of Gelaid was proven in this study. The number of ECT electrode pad installations for appropriate impedance was less in the Gelaid group than that in the PRE TAC group.

Improved contact between the skin and ECT electrode pads

Uniform and sufficient contact between the ECT electrode pad and the skin has to be confirmed. High impedance between the pads due to inappropriate contact can cause skin burns during ECT.^{8,9} Scalp hair at the pad-placement site often hinders proper contact by inserting itself between the pad and the skin and can cause unexpected high impedance just before electric discharge, despite the fact that it might initially gain moderate impedance before general anesthesia. Occasionally, shaving of the hair or non-standard placement of the pads has to be considered, as it may lead to the patient's refusal of ECT or inefficient stimulation. When using PRE TAC, its conductive salts will stay on the hair and provide some conductivity. Gelaid also enfolds hairs and makes them part of a conductive gel layer. The solvent from the former agent must be dried up by the end of the skin preparation. As a result, several high impedance patches with a mixture of air and hair may remain between the pad and the skin. Conversely, Gelaid comprises an evenly conductive layer between the pad and the skin by replacing the air and enfolding nonconductive hair with conductive gel. Skin burns did not occur in our study. Gelaid showed significant reductions in both skin preparation times and impedance, thus suggesting that the use of conductive gel can improve pad attachment, smooth ECT performance, and also lead to a reduction in the occurrence of adverse events such as skin burns. Additionally, with Gelaid, the appearance problems associated with shaving will be avoided, and a patient's consent to undergo ECT will be more likely, especially at the outpatient clinic from where patients return home after ECT procedures.

Increasing the safety and versatility of ECT

The versatility of electrode pad placement should be maintained. In most cases, standard bilateral placement of electrodes is selected according to the recommendations outlined in several different guidelines.^{2,6} Standard bilateral placement of ECT electrode pads is generally most effective for treatment and rapid and thorough recovery in most cases. However, bilateral placement can cause more severe cognitive disorientation than other applicable methodologies (e.g., unilateral placement). Additionally, sometimes supportive care for such cognitive deficits may be required

even after discharge, especially in elderly patients. Therefore, the electrode placement other than bilateral placement (e.g., right unilateral, bifrontal, or left anterior right temporal placements) is determined according to the severity of illness and the physical and cognitive states of the patient.⁷ In many cases, however, the area determined for placement is partially or completely covered with scalp hair, and acquiring proper skin-electrode contact is difficult using PRE TAC. These results show that using conductive gel avoids such problems and provides ECT practitioners with a high degree of freedom for electrode placement.

Limitations

When comparing the two conductive agents in the present study, the defibrillator gel was considered to be suitable for ECT from all perspectives. There were a few limitations. Because Gelaid was the only defibrillator gel used in the study, it is unclear which of the two agents used for similar applications would be superior. Because there was a small study population, there were scant treatment conditions identified. Finally, all the patients were women with depression which likely had an impact on the generalizability of these findings. Therefore, it is warranted to investigate: 1) whether these results can be reproduced under similar conditions, 2) whether the results can be reproduced when there is a unilateral electrode placement where a higher impedance is expected,¹⁷ and 3) whether these methods can be used for other mental illnesses or applied by different therapists. This study suggests that defibrillator gels can be safely used in ECT and insure adequate skin preparations for ECT.

Acknowledgements

The authors thank Editage for editing the manuscript.

Conflicts of Interest: None

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