Brain Tumors and Electroconvulsive Therapy: A Literature Overview of the Last 80 Years

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The safety and efficacy of electroconvulsive therapy (ECT) in patients with a brain tumor have been debated in the past without a clear conclusion. In the last large review published by Maltbie et al. in 1980, it was deemed that the presence of an intracranial mass should be considered an absolute contraindication to ECT. In our updated review, we investigated a total of 33 published and indexed case reports, case report series, and reviews of 75 individual patients who underwent ECT in the presence of a brain tumor over the last 80 years. Mounting case reports after the original Maltbie et al. review show that it is feasible to apply this method safely in patients with benign or otherwise clinically insignificant lesions. Certain precautionary measures, such as dexamethasone or phenytoin application before ECT, could lead to a further minimalization or even absence of adverse effects, particularly in higher risk individuals.

Keywords: ECT, brain tumor, abnormal recovery, ECT safety, ECT and cancer

INTRODUCTION

The safety and efficacy of electroconvulsive therapy (ECT) in patients with a brain tumor were debated in the past without a clear conclusion. In the last large review published by Maltbie et al. (1) in 1980, it was deemed that the presence of an intracranial mass should be considered an absolute contraindication to ECT. In our updated review, we investigated a total of 33 published and indexed case reports, case report series, and reviews of 75 individual patients who underwent ECT in the presence of a brain tumor over the last 80 years.

STUDY AIM

The main aim of our review was to find out whether the original conclusion of Maltbie et al. (1) (the presence of a brain tumor should be considered an absolute contraindication to ECT) can be challenged by collecting and analyzing all case reports, case report series, or mini reviews that emerged on this topic since the publication of this review 40 years ago. Our secondary goal was to provide a comprehensive overview about the occurrence and severity of adverse effects (AEs) after ECT in patients with a brain tumor and find possible methods to increase the safety of this important treatment modality in current scientific literature.
METHODS

We followed the PRISMA statement (2) as a guide for conducting our systematic review. We have searched the electronic databases of Cochrane, PubMed, Journal of ECT, Biological Psychiatry, and Brain Stimulation using combinations of terms “electroconvulsive therapy,” “brain tumor,” and “electroconvulsive therapy,” “intracranial mass,” and “ECT,” “brain tumor.” The search was last updated in May 2020. The electronic search returned 651 abstracts and titles. We screened these abstracts and excluded studies that were duplicates or not directly relevant to the topic of this review. Our inclusion criteria were all original studies—case reports, letters to the Editor, case report series, mini reviews, reviews, or book chapters.
The same weakness was pointed out by Maltbie et al. (1) and were already discussed in the Maltbie et al. (1) review. Nonetheless, we have summarized the available data from these individual case reports in Table 1. Because of the large variability in the quality of these articles up to 1980, we have focused our attention to summarize newer case reports, case report series, or mini reviews published between 1984 and 2020 (Table 2).

Outcome data were determined by scoring several questions:

- Were there any neurological symptoms present before ECT?
- Was the presence of the tumor known before ECT?
- What was the type of ECT used—pulse width, electrode placement, dosage, titration strategy?
- Were there any AEs present after ECT, especially neurological and lateralizing symptoms?
- Was ECT discontinued due to the presence of any AEs?
- What was the indication for ECT?
- Was the application of ECT beneficial for the patients according to the authors of the respective case report?
- How many sessions of ECT were applied?
- Were any precautionary measures undertaken if the presence of the brain tumor was known before ECT application?

Despite the large variation in quality and quantity of the information provided, we were also able to sort patients by their biological sex, age, type, localization, and size of the tumor.

### STUDY LIMITATIONS

The main bias of our review is the fact that the topic of ECT and brain tumor is likely underreported in general. The same weakness was pointed out by Maltbie et al. (1) in their original study from 1980. It is very likely that a substantial amount of patients with an undiagnosed brain tumor undergo this treatment without any observable side effects and are therefore not reported in scientific literature. On the other hand, it is possible that AEs after ECT treatment in this subgroup of patients are also underreported, as the newer case reports after 1980 consist largely of patients with clinically insignificant tumors. More advanced investigations, such as the analysis of registry-based data [health maintenance organization (HMO)/insurance claims, government regulation data] could provide a more clear and complex view of this topic.

Another weakness is the varied quality of the presented case reports. In particular, the authors generally did not specify as to how exactly the AEs were monitored after ECT (nor to what extent the patients were neurologically examined prior to ECT). It is therefore possible that these patients did manifest discreet symptoms that were not noticed and only the more obvious AEs were reported.

### RESULTS

Starting from the first case report by Hsiao and Evans (14) in 1984 up to our own in 2019, we reviewed a total of 40 patients, which represents a comparable size-sample to the one analyzed by Maltbie et al. (1) between the years 1945 and 1980 (total of 35). In contrast with the previous review, the presence of a brain tumor was known before ECT in 29 patients (72.5%). Brief pulse width ECT was administered to 28 patients, ultrabrief pulse width to three, and in nine patients, we were unable to trace the pulse width.

The most common indication for ECT in this group of patients was severe depression (18 patients—45%) and psychosis, usually associated with a severe mood disorder (18 patients—45%). Three patients were indicated for ECT due to symptoms of catatonia and one patient for mania.

The most common type of tumor was a meningioma, which was present in 16 patients (40%), with arachnoid cysts coming in second place with 11 patients (27.5%).

Six patients (15% of the sample) manifested AEs after ECT. Out of this group, four patients developed postictal confusion; one patient manifested a set of several unusual, but reversible, symptoms (secondary myoclonic seizure with lateralization unresponsive to intravenous diazepam application, ping-pong gaze, and Todd’s paralysis); and one patient was observed to develop a 3-day-long delirium with hearing impairment. All reported AEs were reversible.

ECT was discontinued in six patients (15%)—the first described by Holroyd (22) in 1993, where the treatment was stopped immediately after a random CT scan revealed a tumor in the pituitary area. Ironically, the patient did not show any AEs during ECT administration, and at the time, it was stopped only due to the previous series of negative case reports on the topic. The second cessation of ECT was in the case of an 80-year-old woman due to terminal-stage cancer (24). In another two cases, the ECT was canceled due to lack of effect and refusal to continue with the procedure from the side of the patient (28, 29). Huang et al. (30) described a patient who developed severe AEs after ECT including nausea, hearing loss, and a 3-day delirium—the patient was later diagnosed with acoustic neuroma, and ECT was discontinued. And finally, in our department, we halted ECT in a female patient who manifested a secondary seizure and was subsequently found to have an intracranial tumor in the left parietal lobe (25).
| Study          | Sex | Age | Neurological symptoms prior to ECT | Type of tumor | Localization | Was tumor presence known before ECT? | Type of ECT | Number of ECT applications | Adverse Effects after ECT |
|---------------|-----|-----|-----------------------------------|---------------|--------------|-------------------------------------|-------------|---------------------------|--------------------------|
| Rond (4)      | M   | 42  | No                                | Glioma        | Pons         | No                                  | Unknown     | 3                         | Long-term confusion and ataxia |
| Dressler et al. (5) | F   | 66  | No                                | Metastatic carcinoma | Left parietal and left occipital lobe | Yes         | Unknown                  | 7                         | No                       |
| Shapiro and Goldberg (6) | M   | 60  | No                                | Meningioma    | Frontal lobe | No                                  | Unidirectional current (Reiter machine) | 3                         | Long-term confusion        |
| Shapiro and Goldberg (6) | M   | 39  | Neck and facial pain              | Meningioma    | Right sphenoidal ridge | No                              | Unidirectional current (Reiter machine) | 6                         | Long-term confusion        |
| Shapiro and Goldberg (6) | M   | 70  | Dyscalculia, hand extinction      | Glioblastoma multiforme | Right fronto-temporal region | No                              | Unidirectional current (Reiter machine) | 7                         | Long-term confusion, aphasia |
| Shapiro and Goldberg (6) | M   | 69  | Memory defects, truncal ataxia    | Glioblastoma  | Corpus callosum | No                              | Unidirectional current (Reiter machine) | 5                         | Long-term confusion        |
| Shapiro and Goldberg (6) | M   | 47  | Paresis of the right lower extremity, severe recurrent headaches | Glioblastoma | Left frontal lobe | No                              | Unidirectional current (Reiter machine) | 4                         | Aphasia                   |
| Shapiro and Goldberg (6) | M   | 56  | No                                | Glioblastoma  | Left temporo-parietal region | No                              | Unidirectional current (Reiter machine) | 2                         | No                       |
| Gassel (7)    | F   | 42  | Headaches with vomiting           | Meningioma    | Right frontal lobe | No                              | Unknown     | 1                         | Long-term confusion, weakness in all limbs |
| Gassel (7)    | F   | 40  | Weakness in right lower extremity | Meningioma    | Left parietal lobe | No                              | Unknown     | 4                         | Memory deficit complaints, weakness in all limbs |
| Gassel (7)    | F   | 55  | Headaches with vomiting, indeterminate right plantar response | Meningioma    | Right parieto-occipital lobe | No                              | Unknown     | 4                         | Aphasia, right miosis, bilateral acute papilledema, spasticity of lower extremities |
| Grainick (8)  | M   | 60  | No                                | Meningeal fibroblastoma | Both frontal lobes | No                              | Unidirectional current | 2                         | Coma                      |
| Cole (9)      | M   | 33  | No                                | Oligodendroglioma | Left frontal lobe + both lateral ventricles | No                              | Unknown     | 5                         | Long-term confusion, coma |

(Continued)
TABLE 1 | Continued

| Study                     | Sex | Age | Neurological symptoms prior to ECT | Type of tumor | Localization | Was tumor presence known before ECT? | Type of ECT | Number of ECT applications | Adverse Effects after ECT |
|---------------------------|-----|-----|-----------------------------------|---------------|--------------|--------------------------------------|-------------|-----------------------------|--------------------------|
| Delay et al. (10)         | F   | 42  | No                                | Glioma        | Left-parieto-temporal region         | No                      | Unknown              | 6                        | Secondary seizure after ECT with right-sided lateralisation |
| Malamud (11)              | M   | 47  | Epileptiform attacks              | Astrocytoma    | Left temporal lobe                   | No                      | Unknown              | Unknown                  | No                       |
| Malamud (11)              | F   | 27  | No                                | Astrocytoma    | Right fronto-parietal region         | No                      | Unknown              | Unknown                  | Left-side spasticity     |
| Malamud (11)              | M   | 26  | No                                | Glioma         | Hippocampus                          | No                      | Unknown              | Unknown                  | Epileptic seizures after combined ECT/insuline treatment |
| Malamud (11)              | F   | 47  | Epilepsy                          | Astrocytoma    | Left temporal lobe                   | No                      | Unknown              | Unknown                  | Syncopes after ECT and one record of transient aphasia |
| Malamud (11)              | M   | 33  | Epilepsy                          | Astrocytoma    | Left frontal lobe                    | No                      | Unknown              | Unknown                  | Coma                     |
| Malamud (11)              | F   | 48  | No                                | Craniopharyngioma | Third ventricle                    | No                      | Unknown              | Unknown                  | Dysarthria and subsequent coma |
| Malamud (11)              | M   | 28  | No                                | Colloid cyst    | Third ventricle                      | No                      | Unknown              | Unknown                  | Coma                     |
| Paulson (12)              | F   | 49  | Headache, dyscomfort in right shoulder | Metastatic carcinoma | Right parietal lobe                  | No                      | Unknown              | 1                        | Coma                     |
| Paulson (12)              | M   | 20  | Head and neck pain                | Sarcoma        | Cerebellum                           | No                      | Unknown              | 6                        | Coma, bilateral papilloedema with hemorrhages |
| Paulson (12)              | F   | 57  | Headache, difficulty writing      | Metastatic carcinoma | Left frontal lobe                  | No                      | Unknown              | 1                        | Aphasia, weakness in right upper and lower limb |
| Kainowski and Kippins (13)| Unknown | Unknown | Unknown                           | Unknown        | Unknown                               | No                      | Unknown              | Unknown                  | Unknown                  |
| Maltbie et al. (1)        | F   | 48  | Ataxia                            | Meningioma     | Olfactory groove                     | No                      | Unknown              | 1                        | Coma                     |
| Maltbie et al. (1)        | M   | 46  | No                                | Glioblastoma multiforme | Left parietal lobe               | No                      | Unknown              | 1                        | Long-term confusion, aphasia, left-sided hyperreflexion |
| Maltbie et al. (1)        | F   | 48  | Epilepsy                          | Glial tumor    | Both frontal lobes                   | No                      | Unknown              | 6                        | Ataxia, right hemiparesis, withdrawal |

(Continued)
TABLE 1 | Continued

| Study       | Sex | Age | Neurological symptoms prior to ECT | Type of tumor               | Localization                      | Number of ECT applications | Type of ECT | Number of ECT applications | Adverse Effects after ECT | Neurological symptoms prior to ECT | Type of tumor               | Localization                      | Number of ECT applications | Type of ECT | Number of ECT applications | Adverse Effects after ECT | Neurological symptoms prior to ECT | Type of tumor               |
|-------------|-----|-----|----------------------------------|----------------------------|---------------------------------|-----------------------------|-------------|-----------------------------|-----------------------------|----------------------------------|----------------------------|---------------------------------|-----------------------------|-------------|-----------------------------|-----------------------------|----------------------------------|----------------------------|-----------------------------|
| Mattie et al. (1) | M   | 63  | No                               | Glioblastoma               | Occipital region                | 12                          | Unknown     | Unknown                     | Persistent headache by 5 months, Left hemiplegia | No                               | Unknown                     | Glioblastoma               | Occipital region                | 12                          | Unknown     | Unknown                     | Persistent headache by 5 months, Left hemiplegia | No                               | Unknown                     |
| Mattie et al. (1) | M   | 38  | No                               | Oligodendroglioma          | Right frontal lobe              | 15                          | Unknown     | Unknown                     | No                          | No                               | Oligodendroglioma          | Right frontal lobe              | 15                          | Unknown     | Unknown                     | No                          | No                               | Oligodendroglioma          |
| Mattie et al. (1) | F   | 28  | No                               | Dermoid cyst               | Left frontal lobe               | 1                           | Unknown     | Unknown                     | No                          | No                               | Dermoid cyst               | Left frontal lobe              | 1                           | Unknown     | Unknown                     | No                          | No                               | Dermoid cyst               |
| Mattie et al. (1) | F   | 50  | No                               | Glioblastoma               | Left fronto-temporal region     | 1                           | Unknown     | Unknown                     | No                          | No                               | Glioblastoma               | Left fronto-temporal region     | 1                           | Unknown     | Unknown                     | No                          | No                               | Glioblastoma               |
| Mattie et al. (1) | F   | 54  | No                               | Meningioma                 | Right fronto-parietal region    | 12                          | Unknown     | Unknown                     | No                          | No                               | Meningioma                 | Right fronto-parietal region    | 12                          | Unknown     | Unknown                     | No                          | No                               | Meningioma                 |
| Waggoner and Bagchi (15) | F   | 53  | No                               | Craniopharyngioma           | Left fronto-temporal region     | 3                           | Unknown     | Unknown                     | Yes (suggested)              | No                               | Craniopharyngioma           | Left fronto-temporal region     | 3                           | Unknown     | Unknown                     | Yes (suggested)              | No                               | Craniopharyngioma           |
| Waggoner and Bagchi (15) | F   | 37  | No                               | Chronic headache and dizziness | Oligodendroglioma           | Unknown                  | Unknown     | Unknown                     | No                          | No                               | Chronic headache and dizziness | Oligodendroglioma           | Unknown                  | Unknown                     | No                          | No                               | Chronic headache and dizziness |

Five patients (12.5%) had neurological symptomatology prior to the administration (including one report of a patient with an elevated intracranial pressure), but none of them manifested any AEs following ECT administration. Five patients were premedicated with dexamethasone to prevent acute edema or phenytoin to prevent secondary seizures.

According to the authors of the respective case reports, ECT was beneficial for 36 patients (90%). ECT was ineffective in three cases and discontinued in one patient after he refused to undergo further treatment (the reason behind this decision was not stated).

Only one patient (27) was reported to have had elevated intracranial pressure prior to the procedure, and he underwent ECT without any AEs.

In this group of patients, we were able to determine the exact number of ECT sessions in 36 patients. The average number of sessions per patient was 9.47.

No patient was reported to have died as a result of ECT application in this sample. The average age of patients in this group was 59.72 years.

**DISCUSSION**

There seems to be a clear difference between the two similarly sized groups from 1945 to 1980 and 1984 to 2019. However, our results must also be seen as biased—the topic of ECT and brain tumor is likely in general underreported; in the majority (72.5%) of these new case reports, the presence of the brain tumor was known prior to ECT application which had allowed undertaking specialized precautions (23) (dexamethasone or phenytoin administration) in a substantial number of patients (12.5%), and last but not least, 40% of these reports constitute patients with benign meningiomas or clinically insignificant tumors, which is in contrast to the group of patients reported on by Maltbie et al. (1), where this group represents only seven patients (20%). It should be noted that the latter review consisted of a substantial amount of patients with more aggressive and clinically more significant tumors, such as gliomas (Table 1). We also point out a difference between patients with neurological symptoms manifesting prior to ECT administration—12.5% of patients in the new group and 45.7% in the Maltbie et al. (1) sample.

Despite this bias, the case reports between 1984 and 2019 demonstrate that ECT can be applied safely in certain patients with an intracranial mass. The average number of ECT sessions was 9.47 in this group compared to 4.57 in the older group. Six patients manifested AEs after the treatment—out of these, only two patients discontinued treatment due to their presence. All AEs in the 1984–2019 sample were reversible, and the majority constituted of patients who were confused after the procedure—an AE not that rare even in patients undergoing ECT without a brain tumor.

We know that seizure activity increases blood pressure and cerebral blood flow, which can lead to an increased edema around the tumor and subsequently to an increase in intracranial pressure and eventually manifestation of neurological signs.
| Study                        | Sex | Age | Neurological symptoms prior to ECT | Indication (symptoms) | Type of tumor | Size (cm) | Localization | Was tumor known before ECT | Type of ECT | no. of ECT | Adverse Effects after ECT? | Was ECT beneficial? | Was ECT discontinued? | Notes                                                                 |
|-----------------------------|-----|-----|-----------------------------------|----------------------|---------------|-----------|--------------|---------------------------|-------------|-----------|------------------------------|----------------------|-----------------------|-----------------------------------------------------------------------|
| Hsiao and Evans(14)         | F   | 50  | No                                | Severe depression with psychosis | Meningioma     | Unknown   | Left parietal lobe | Yes                        | Brief       | 18        | No                           | Yes                  | No                    | Patient received phenytoin prior ECT to prevent prolonged seizure    |
| Fried and Mann(16)          | M   | 85  | No                                | Severe depression with psychosis | Meningioma     | 2.0       | Left frontal lobe  | Yes                        | Brief       | 11        | No                           | Yes                  | No                    |                                                                                        |
| Greenberg et al.(17)        | F   | 75  | No                                | Severe depression with psychosis | Meningioma     | 3.0 × 3.0 | Fronto-temporo-parietal region | Yes                        | Brief       | 8         | No                           | Yes                  | No                    |                                                                                        |
| Goldstein and Richardson(18)| F   | 74  | No                                | Severe depression         | Meningioma     | 1.0 × 1.5 | Right frontal lobe | Yes                        | Brief       | 6         | No                           | Yes                  | No                    |                                                                                        |
| Malek-Ahmadi and Sedler(19) | F   | 73  | No                                | Severe depression         | Meningioma     | 0.5       | Fronto-parietal region | Yes                        | Brief       | 7         | No                           | Yes                  | No                    |                                                                                        |
| Zwil et al.(20)             | F   | 73  | No                                | Severe depression with psychosis | Meningioma     | 2.0       | Cerebello-pontine region | Yes                        | Brief       | 10        | Post-ictal confusion         | Yes                  | No                    | Patient received dexamethasone prior ECT                                  |
| Zwil et al.(20)             | F   | 71  | No                                | Severe depression with psychosis | Meningioma     | 1.0 × 1.0 | Left frontal lobe  | Yes                        | Brief       | 12        | No                           | Yes                  | No                    |                                                                                        |
| Zwil et al.(20)             | F   | 78  | No                                | Psychosis                | Meningioma     | 2.0       | Left parietal lobe  | Yes                        | Brief       | 10        | Post-ictal confusion         | Yes                  | No                    | Patient received dexamethasone prior ECT                                  |
| Mattingly et al.(21)        | F   | 75  | No                                | Severe depression         | Meningioma     | 1.2 × 1.2 | Metastatic carcinoma | Yes                        | Brief       | 11        | No                           | Yes                  | No                    | Patient received dexamethasone prior ECT                                  |
| Holroyd (22)                | F   | 83  | No                                | catatonia                | Meningioma     | 1.5 × 1.5 | Left frontal lobe  | Yes                        | Brief       | 18        | No                           | Yes                  | No                    | Discontinued after diag. of tumor due to previous reports              |
| Holroyd (22)                | F   | 83  | No                                | Severe depression         | Meningioma     | 2.0 × 2.0 | Cerebellar region  | Yes                        | Brief       | 20        | No                           | Yes                  | No                    |                                                                                        |
| Holroyd (22)                | M   | 76  | No                                | Severe depression with psychosis | Unknown        | Unknown   | Unknown | No                       | Brief       | 7         | No                           | Yes                  | Yes                   |                                                                                        |
| Study | Sex | Age | Indication (symptoms) | Neurological symptoms prior to ECT | Type of tumor | Size (cm) | Localization | Was tumor known before ECT | Type of ECT no. of ECT | Adverse Effects after ECT? | Was ECT beneficial? | Was ECT discontinued? | Notes |
|-------|-----|-----|-----------------------|-----------------------------------|---------------|----------|-------------|--------------------------|------------------------|--------------------------|----------------------|----------------------|-------|
| Holroyd (22) | F | 65 | Severe depression | Left hyperreflexia and Babinski, oral dyskinesia | Meningioma | 1.5 x 1.5 | Left frontal lobe | Yes | Brief 5 | No | Yes | No |
| Holroyd (22) | M | 60 | Psychosis | | Acoustic neuroma | 4.0 | Left posterior fossa | No | Brief 11 | No | Yes | No |
| Kellner and Rames (23) | F | 75 | Severe depression | | Meningioma | 1.7 x 1.0 | Left frontotemporal region | Yes | Brief 9 | No | Yes | No |
| Rasmussen et al. (35) | M | 71 | Psychosis | | Unknown | 1.5 x 1.0 | Left parietal lobe | No | Brief Unknown | No | Yes | No |
| Rasmussen et al. (24) | M | 59 | Severe depression | | Unknown | 0.2 | Thalamus | Yes | Brief 9 | No | Yes | No |
| Rasmussen et al. (24) | M | 57 | Severe depression | | Unknown | 1.2 parasagittally | Right basal forebrain | No | Brief 6 | No | Yes | No |
| Rasmussen et al. (24) | F | 73 | Severe depression | | Meningioma | 1.0 x 1.7 | Ponto-cerebellar region | No | Brief Unknown | No | Yes | No |
| Rasmussen et al. (24) | F | 80 | Severe depression | | Cystic mass | 3.3 x 2.9 x 3.4 | Frontal lobe | No | Brief Unknown | No | No | Yes |
| Rasmussen et al. (24) | M | 44 | Severe depression | | Unknown | Unknown | Ponto-medullary region | Yes | Brief 8 | No | Yes | No |
| Rasmussen et al. (24) | F | 33 | Severe depression | | Microadenoma0.35 | Unknown | Sellar region | Yes | Brief 10 | No | Yes | No |
| Gani and Parvez (26) | F | 70 | Severe depression | | Meningioma | Unknown | Left parietal lobe | No | Ultrabrief 7 | Secondary seizure after ECT | Yes |
| Patkar et al. (27) | M | 61 | Severe depression | | Astrocytoma | Unknown | Left parietal lobe | Yes | Brief 8 | No | Yes | No |
| Fischer (28) | F | 80 | Severe depression | | Gliostoma multiforme | Unknown | Corpus callosum | No | Ultrabrief 7 | Post-ictal confusion, ataxia | No | Yes |

(Continued)
| Study                  | Sex | Age | Indication (symptoms) | Neurological symptoms prior to ECT | Type of tumor | Size (cm) | Localization | Was tumor known before ECT | Type of ECT no. of ECT | Adverse Effects after ECT? | Was ECT beneficial? | Was ECT discontinued? | Notes                                                                 |
|-----------------------|-----|-----|-----------------------|------------------------------------|---------------|-----------|-------------|---------------------------|-------------------------|------------------------|----------------------|------------------------|--------------------------|
| Perry et al. (29)     | F   | 53  | Severe depression     | No                                 | Arachnoid cyst | 4.0 × 4.4 × 1.6 | Left-frontoparietal convex. | Yes                       | Unknown 11              | No                     | Yes                    | No                      | Patient refused further ECT (reason not stated) |
| Perry et al. (29)     | M   | 58  | psychosis with agitation | No                                 | Arachnoid cyst | 1.3 × 4.3 × 1.4 | Left posterior fossa        | Yes                       | Unknown 21              | No                     | Yes                    | No                      |                                        |
| Perry et al. (29)     | M   | 43  | Severe depression     | No                                 | Arachnoid cyst | 2.0 × 2.0 × 2.5 | Midline posterior fossa     | Yes                       | Unknown 14              | No                     | Yes                    | No                      |                                        |
| Perry et al. (29)     | M   | 19  | Mania with psychosis  | No                                 | Arachnoid cyst | 3.0 × 5.0 × 4.0 | Middle cranial fossa        | Yes                       | Unknown 1               | No                     | No                     | Yes                      |                                        |
| Perry et al. (29)     | M   | 42  | Catatonia             | No                                 | Arachnoid cyst | 2.6 × 1.2 × 2.9 | Left posterior fossa        | No                        | Unknown 5               | No                     | Yes                    | No                      |                                        |
| Perry et al. (29)     | M   | 44  | Severe depression with psychosis | No                                 | Arachnoid cyst | 1.3 × 3.5 × 2.3 | Middle cranial fossa        | Yes                       | Unknown 5               | No                     | Yes                    | No                      |                                        |
| Huang et al. (30)     | F   | 58  | Severe depression     | No                                 | Acoustic neuroma | 3.3 at CP angle | Left cerebello-pontine angle | No                        | Brief 6                | Post-ictal confusion, delirium, nausea, hearing impairment | No                     | Yes                    | No                      |                                        |
| Deseilles et al. (31) | M   | 58  | Severe depression     | No                                 | Arachnoid cyst | 7.6 × 4.1 × 8.1 | Right anterior temporal reg. | Yes                       | Brief 7                | No                     | Yes                    | No                      |                                        |
| Hanretta et al. (32)  | F   | 29  | Severe depression with psychosis | No                                 | Arachnoid cyst | 2.5 × 2.5       | Right temporal lobe         | Yes                       | Brief 6                | No                     | Yes                    | No                      |                                        |
| Kastenholz et al. (33)| F   | 21  | Catatonia             | No                                 | Arachnoid cyst | 4.6 × 8.8 × 4.0 | Posterior fossa             | Yes                       | Brief 6                | No                     | Yes                    | No                      |                                        |
| Escalona et al. (34)  | M   | 53  | Severe depression     | No                                 | Arachnoid cyst | Unknown         | Left sylvian fissure        | Yes                       | Unknown Unknown         | No                     | Yes                    | No                      |                                        |
| Restifo and Paterson (35) | M   | 22  | Psychosis             | No                                 | Colloid cyst   | Unknown         | Third ventricle             | Yes                       | Unknown 9               | No                     | Yes                    | No                      |                                        |
| Grover et al. (36)    | F   | 57  | Severe depression with psychosis | No                                 | Arachnoid cyst | 3.4 × 1.6       | Left temporal region        | No                        | Unknown 12              | Post-ictal confusion | Yes                    | No                      |                                        |
| Mckinney et al. (37)  | F   | 66  | mania                 | No                                 | Meningioma     | 1.0            | Cerebellum                | Yes                       | Brief 8                | No                     | Yes                    | No                      |                                        |
This mechanism was first proposed by Carter (38) in 1977 and considered to be the likely cause of the more prominent AEs in this review reported by Huang et al. (30) and Buday et al. (25).

Dexamethasone was used in a substantial amount of patients (12.5%) to reduce the risk of this pathophysiological mechanism in the newer set of case reports. Phenytoin was administered to one patient to prevent a prolonged seizure. None of these individuals manifested AEs; it is therefore possible that the administration of these substrates prior to ECT may reduce the risk of an acute edema and prolonged seizure, respectively.

In their review, Maltbie et al. (1) suggested that more invasive and aggressive tumors might result in a higher incidence of AEs during ECT. The majority of patients in the newer case reports had benign, small, and clinically insignificant tumors, which seem to support the conclusion that this type of lesion poses a minimal risk increase in regard to ECT application. However, as several new case reports mention in this review, some patients with a brain tumor (especially a previously undiagnosed lesion) can manifest reversible, but unusual and concerning, AEs. Currently, neuroimaging is not mandatory before initiating ECT—it was reported several times that the yield of organic pathology if performed in all patients before undergoing ECT is very low (34, 39, 40). We suggest that any new neurological symptoms manifesting during and after ECT (such as a significant lateralization of the seizure, Todd's paralysis, aphasia, eye-movement disorders, secondary seizures, etc.) should prompt a complex neurological investigation and neuroimaging to exclude the presence of an intracranial mass (which might, depending on its localization, play a role in the psychopathology due to which ECT was indicated in the first place), another organic disease of the central nervous system, or even an acute problem, such as intracranial bleeding.

We must also consider that technological advancement and modern titration strategies that seek to individualize the dosage in each patient might also be one of the reasons why there are less and far more benign and reversible reported AEs (41). Unfortunately, in most cases between 1945 and 1980, it was not possible to track the type of devices, titration strategy, and dosage levels used during ECT. Based on the review of case reports emerging since 1984, it seems that the application of ECT is safer than it was originally presumed by Maltbie et al. (1) in 1980, and this method can be applied safely on a case-by-case basis.

CONCLUSION

We have reviewed a total of 33 articles of 75 individual patients who underwent ECT in the presence of a brain tumor over the last 80 years. Mounting case reports from 1984 show that this method can be safely administered in patients with benign, small, and otherwise clinically insignificant tumors. The application of ECT in this type of patients should be considered in a case-by-case basis after interdisciplinary consultation with a neurologist and neurosurgeon with a risk/benefit assessment. ECT practitioners should be vigilant of any AEs (especially neurological) manifesting during and after the procedure. The occurrence of such abnormal symptoms should prompt an immediate neurological investigation and proper imaging studies to exclude any underlying organic pathology. Certain precautionary measures, such as dexamethasone or phenytoin application before ECT, could lead to a further minimalization of AEs.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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