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Effect of application of monopolar electrocautery to the middle ear with different power settings on the inner ear

Remzi DOĞAN
Bezmiâlem Vakıf Üniversitesi
İsmail Çelik
Şişli Etfal Eğitim ve Araştırma Hastanesi
Meliha Başöz
Bezmiâlem Vakıf Üniversitesi
Özge Gedik
Bezmiâlem Vakıf Üniversitesi
Mehmet Şerif Aydın
Istanbul Medipol University
Muhammed Furkan Özgan
furkanozgan45@gmail.com
Afyonkarahisar Devlet Hastanesi
Sabri Baki Eren
Bezmiâlem Vakıf Üniversitesi
Orhan Özturan
Bezmiâlem Vakıf Üniversitesi
Erol Şentürk
Bezmiâlem Vakıf Üniversitesi

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Abstract

Background

Monopolar electrocautery is widely used in otolaryngology and head and neck surgery for tissue dissection and hemostasis. However, its application during middle ear surgery remains controversial because of concerns regarding potential thermal and electrical injury to the cochlea and facial nerve. Although previous investigations have examined the effects of monopolar electrocautery in patients or cadavers with cochlear implants, limited evidence is available regarding its direct application to the promontory. The present experimental study aimed to investigate the short-term audiological and histopathological effects of monopolar electrocautery applied to the promontory at different power settings in a rat model.

Results

The experiment involved 32 healthy female Sprague–Dawley rats weighing 200–240 g, distributed equally among four groups. Three groups received a single transtympanic monopolar electrocautery application to the promontory at 5, 10, or 20 W, while the remaining animals formed an untreated control group. Electrocautery was delivered through a needle-tip electrode under microscopic visualization for 2 seconds. Auditory assessments consisted of distortion product otoacoustic emission (DPOAE) and auditory brainstem response (ABR) recordings obtained before the intervention and on days 7 and 14. The reported statistical comparisons did not demonstrate significant changes in either DPOAE amplitudes or ABR thresholds over the observation period in any group ($p > 0.05$). Histopathological examination of cochlear specimens collected after the final audiological assessment showed no overt nuclear degeneration or loss in the examined hair cells. Hydropic degeneration and nuclear loss were likewise absent in the evaluated spiral ganglion cells and cochlear nerve fibers. No significant between-group differences were reported in the assessed histopathological parameters.

Conclusions

In this experimental rat model, a single 2-second application of monopolar electrocautery to the promontory at 5, 10, or 20 W was not associated with statistically significant changes in the measured auditory parameters or overt cochlear abnormalities on conventional histopathological examination during the 14-day study period. Nevertheless, these observations do not establish the clinical safety of monopolar electrocautery near the cochlea, and further investigation is required.

Background

Monopolar electrocautery is commonly employed in otolaryngology and head and neck surgery because it facilitates tissue dissection and provides effective hemostasis. Despite its widespread use in other

anatomical regions, its application in middle ear surgery is generally approached with caution. The main concerns arise from the potential transmission of electrical energy and heat to adjacent structures, particularly the cochlea and facial nerve. Because of the close anatomical relationship between these structures and the middle ear cavity, unintended tissue injury may occur during electrosurgical procedures. Nevertheless, evidence concerning the actual effects of monopolar electrocautery on the inner ear remains limited.

Previous investigations have primarily focused on the safety of monopolar electrocautery in the presence of cochlear implants. Jeyakumar et al. [1] conducted an experimental study using fresh human cadavers fitted with cochlear implants from three different manufacturers. Following implantation through the cochlear opening, monopolar electrocautery was applied to the tongue and abdominal regions. Intracochlear perilymph temperature was monitored during electrocautery activation, and the implanted devices were subsequently evaluated by their respective manufacturers. The investigators reported no detectable device abnormalities and no increase in perilymph temperature during the tested exposure, which included electrocautery application at 50 W for 30 minutes.

In a subsequent cadaveric investigation, Jeyakumar et al. [2] examined the effects of different electrosurgical modalities in specimens containing cochlear implants. Electrocautery was applied to the ipsilateral pectoralis major or temporalis muscle at power settings ranging from 50 to 100 W. The experimental conditions included bipolar electrocautery, monopolar coagulation, and monopolar cutting modes. No apparent damage to the cochlear implants was identified under the investigated conditions. However, the limited number of cadaveric specimens and the differences in electrical conductivity and physiological characteristics between cadaveric and living tissues restrict the interpretation of these findings.

Clinical evidence is similarly limited. Tien et al. [3] described two patients with cochlear implants who underwent procedures involving electrocautery in the head and neck region. No apparent adverse implant-related outcomes were reported in these cases. Nevertheless, the authors emphasized the need for further investigations and longer follow-up before the routine use of monopolar electrocautery in such circumstances could be recommended.

Although these studies provide useful information regarding electrosurgical exposure in cochlear implant recipients, their findings cannot be directly extrapolated to the effects of monopolar electrocautery applied to the middle ear promontory. In particular, electrocautery activation at distant anatomical sites differs substantially from direct contact with the bony surface overlying the cochlea. Furthermore, cadaveric investigations and clinical case reports do not adequately characterize the functional and histopathological responses of the living cochlea to direct electrosurgical exposure.

Therefore, the present study was designed to investigate the audiological and histopathological effects of monopolar electrocautery applied directly to the promontory at different power settings in an experimental rat model. Cochlear function was evaluated using distortion product otoacoustic emissions and auditory brainstem responses, while structural changes were assessed through

conventional histopathological examination. By combining these evaluation methods, we aimed to investigate potential short-term inner ear alterations following a single monopolar electrocautery application.

Methods

Animals and study design

The study included 32 healthy female Sprague–Dawley rats with body weights ranging from 200 to 240 g. Eligibility was established through an otological examination and assessment of the Preyer reflex. Endoscopic inspection was used to identify abnormalities involving the external or middle ear, while an acoustic stimulus was used to assess the Preyer reflex, an involuntary movement elicited by sound. Animals were excluded if pathological findings were detected during the examination or if the Preyer reflex could not be elicited.

Environmental conditions were standardized throughout the experimental period. The animals were maintained at a room temperature of 21 ± 1°C, with ambient noise levels kept below 50 dB. Food and water were provided without restriction. All animal care and experimental procedures were conducted in accordance with the National Laboratory Animal Protection and Use Regulations.

A comparable animal screening and housing protocol has been described in a previous experimental investigation by Dogan et al. [8].

The 32 rats were divided into four groups, each consisting of eight animals. Three groups underwent monopolar electrocautery application at different power settings, while the fourth group served as an untreated control. In the experimental groups, electrocautery was applied directly to the promontory through a transtympanic approach under microscopic visualization. A monopolar needle-tip electrode was used, and the activation period was standardized to 2 seconds. The applied power differed between groups as described below.

Group 1 (5 W monopolar electrocautery)

Following baseline audiological evaluation, monopolar electrocautery was applied transtympanically to the promontory at a power setting of 5 W for 2 seconds under microscopic visualization. No additional intervention was performed after cauterization. Audiological examinations were subsequently repeated on days 7 and 14.

Group 2 (10 W monopolar electrocautery)

After obtaining baseline audiological measurements, the promontory was exposed to a single 2-second application of monopolar electrocautery at 10 W using the same transtympanic approach and microscopic guidance. No further intervention was performed, and audiological assessments were repeated on days 7 and 14.

Group 3 (20 W monopolar electrocautery)

Following baseline measurements, monopolar electrocautery was applied to the promontory at 20 W for 2 seconds under microscopic visualization using the same transtympanic technique. No additional procedure was performed after the intervention. Follow-up audiological examinations were conducted on days 7 and 14.

Group 4 (Control)

Rats assigned to the control group underwent baseline audiological assessment without subsequent electrocautery application or other experimental intervention. Audiological measurements were repeated on days 7 and 14 according to the same follow-up schedule used in the experimental groups.

Thus, all groups underwent audiological assessments at three time points: before the experimental intervention (baseline) and on days 7 and 14. Following completion of the audiological follow-up, cochlear specimens were collected for histopathological examination.

Audiological evaluation

Auditory assessments were scheduled at three stages of the experiment: before the intervention and on days 7 and 14. At each examination, anesthesia was administered intraperitoneally using ketamine hydrochloride (40 mg/kg) combined with xylazine (5 mg/kg).

Two complementary techniques were employed to evaluate auditory function. Distortion product otoacoustic emission (DPOAE) testing was used to investigate cochlear outer hair cell activity, whereas auditory brainstem response (ABR) recordings were obtained to assess electrophysiological responses generated along the auditory pathway. To maintain consistency between examination sessions, all audiological measurements were performed by a single examiner.

Distortion product otoacoustic emissions (DPOAE)

Cochlear responses were investigated using an otoacoustic emission recording system manufactured by Intelligent Hearing Systems (IHS, USA). Examinations were conducted in a soundproof chamber, with the smallest available tympanometry probe attached to the recording equipment.

Before data acquisition, the probe was positioned in the external auditory canal, and the suitability of its placement was confirmed by examining the probe indicator and stimulus waveform. Recordings were initiated only after the appropriate measurement configuration had been established.

Two primary tones were presented at fixed stimulus levels of 65 dB (L1) and 55 dB (L2). The frequency relationship between these stimuli was defined by an f2/f1 ratio of 1.20.

Emission amplitudes were measured using DP-gram recordings across 13 frequencies: 358, 498, 701, 997, 1401, 1977, 2834, 4002, 5636, 7988, 11288, 15991, and 22608 Hz. This frequency range permitted assessment of cochlear responses extending into the high-frequency region.

For interpretation of the recordings, an emission was accepted as detectable when its amplitude was at least 3 dB above the corresponding noise floor. Measurements were obtained throughout the specified frequency range, and the examination was concluded after completion of the scheduled recordings.

Auditory brainstem responses (ABR)

ABR measurements were performed with an Intelligent Hearing Systems (IHS, USA) recording device in a soundproof chamber. Responses were acquired from both ears of anesthetized rats using needle electrodes inserted subcutaneously. Acoustic stimuli were delivered through insert earphones.

Auditory responses were elicited using alternating-polarity stimulation at 8, 16, 20, and 32 kHz. During data acquisition, the recording system was operated with a 30–1500 Hz bandpass filter, a stimulation rate of 21.1 presentations per second, and a 25-ms recording window. Each waveform represented the averaged response to 1024 stimulus presentations.

The ABR threshold search began at a stimulus intensity of 80 dB nHL. Stimulus levels were initially lowered in 20-dB steps until the response approached the estimated hearing threshold. Thereafter, smaller 10-dB adjustments were used to refine the threshold estimate.

Wave II was selected as the reference component for threshold identification. The lowest stimulus level at which this component remained clearly identifiable was recorded as the ABR threshold, provided that the response could be confirmed in at least two separate recordings. The corresponding waveforms were examined together to verify the reproducibility of wave II before the final threshold was assigned.

The same recording settings and threshold determination procedure were used at baseline and during the subsequent evaluations on days 7 and 14.

A comparable audiological assessment protocol has previously been described in an experimental investigation by Dogan et al. [8].

Histopathological evaluation

Cochlear specimens were collected for histopathological examination after the audiological follow-up was completed on day 14. Tissue preparation began with fixation in 10% neutral buffered formalin for 72 hours. The fixed specimens subsequently underwent decalcification in an ethylenediaminetetraacetic acid (EDTA) solution prepared with 100 mL of 0.1 M phosphate buffer. This process was maintained at 4°C for one month, during which the decalcifying solution was renewed at 48-hour intervals.

Following decalcification, the cochlear specimens were prepared for paraffin embedding. Water was progressively removed from the tissues using an ascending ethanol series comprising 70%, 90%, 96%, and 100% concentrations. Xylene was then used as the clearing agent. The specimens were immersed in paraffin overnight at 60°C before being embedded in paraffin blocks.

Sections of 5 μm thickness were obtained from the processed tissues and stained with hematoxylin and eosin (H&E). Microscopic examination was performed using an Axio Zoom V16 microscope (Zeiss).

The histopathological assessment focused on three cochlear components: hair cells, spiral ganglion cells, and cochlear nerve fibers. These structures were examined for morphological evidence of cellular injury, with particular attention to hydropic degeneration and nuclear loss.

A four-level semiquantitative system was used to describe the severity of the observed changes. Findings were classified as absent (−), mild (+), moderate (++), or severe (+++). Histopathological observations from the three electrocautery groups were compared with those obtained from the untreated control group.

A comparable cochlear tissue-processing and histopathological assessment protocol has been reported in a previous experimental study by Dogan et al. [8].

Statistical analysis

The statistical evaluation was conducted using SPSS version 24.0 (SPSS Inc., Chicago, IL, USA). Numerical variables were described using the mean, standard deviation, and median. The Kolmogorov–Smirnov test was applied to assess whether the data followed a normal distribution.

Between-group differences in auditory brainstem response (ABR) thresholds, distortion product otoacoustic emission (DPOAE) amplitudes, and histopathological parameters were examined using the Kruskal–Wallis test. When comparisons between individual groups were undertaken, the Mann–Whitney U test was employed.

Statistical significance was defined as $p < 0.05$.

Manuscript preparation: ChatGPT (OpenAI) was used to assist with English-language editing and organization of the text. No experimental measurements or statistical analyses were generated using this tool.

Results

Audiological evaluation

Auditory function was assessed through DPOAE and ABR recordings obtained at baseline and during the two follow-up examinations on days 7 and 14. The measurements were evaluated to identify changes in

auditory responses following monopolar electrocautery exposure at different power settings. The findings for each group are illustrated in Figs. 1 and 2.

Group 1 (5 W)

In animals receiving monopolar electrocautery at 5 W, DPOAE amplitudes recorded during follow-up did not differ significantly from the baseline measurements according to the reported statistical comparisons. ABR thresholds also remained without statistically significant changes across the three assessment periods ($p > 0.05$). These measurements are shown in Figs. 1a and 2a.

Group 2 (10 W)

Examination of the audiological recordings from the 10 W group revealed no statistically significant alterations in either DPOAE amplitudes or ABR thresholds during the 14-day observation period ($p > 0.05$). The corresponding recordings obtained before exposure and at both follow-up visits are presented in Figs. 1b and 2b.

Group 3 (20 W)

Despite exposure to the highest power setting investigated, no statistically significant changes were reported in the DPOAE or ABR measurements obtained from this group ($p > 0.05$). The baseline findings and subsequent recordings on days 7 and 14 are illustrated in Figs. 1c and 2c.

Group 4 (Control)

The untreated animals were examined at the same time points as the electrocautery-exposed groups. The reported comparisons of DPOAE amplitudes and ABR thresholds did not demonstrate statistically significant changes over time ($p > 0.05$). The results for the control group are displayed in Figs. 1d and 2d.

Taken together, the reported audiological findings showed no statistically significant deterioration in the measured DPOAE amplitudes or ABR thresholds over the 14-day follow-up period in any of the study groups.

Histopathological evaluation

Cochlear tissues obtained after the final audiological measurements were examined to determine whether exposure to monopolar electrocautery had produced identifiable morphological alterations.

Assessment of the hematoxylin-and-eosin–stained sections focused on the hair cells, spiral ganglion cells, and cochlear nerve fibers. No evidence of nuclear degeneration or nuclear loss was identified in the examined cochlear hair cells. The spiral ganglion cells and cochlear nerve fibers likewise exhibited no detectable hydropic degeneration or nuclear loss.

The evaluated cochlear structures maintained their overall morphological appearance in all three electrocautery groups, with findings comparable to those observed in untreated animals. No statistically significant differences in the reported histopathological parameters were identified among the groups ($p > 0.05$).

Representative cochlear sections illustrating the histological findings in the control, 5 W, 10 W, and 20 W groups are provided in Fig. 3.

Discussion

Electrosurgical instruments are widely used in otolaryngological procedures to facilitate tissue dissection, achieve hemostasis, and reduce operative time. Monopolar and bipolar electrocautery are among the most frequently employed techniques for these purposes [4]. Nevertheless, their application in middle ear surgery requires particular attention because of the restricted operative space and the proximity of important anatomical structures, including the cochlea and facial nerve. Although bipolar electrocautery allows more localized delivery of electrical energy, its use may be technically challenging in narrow surgical fields. Monopolar electrocautery may provide greater maneuverability in certain circumstances; however, its potential effects on adjacent tissues remain a concern.

Unlike bipolar electrocautery, monopolar electrocautery involves the passage of electrical current from the active electrode through the patient's tissues toward a return electrode positioned elsewhere on the body. Consequently, tissue injury may occur beyond the immediate contact area of the active electrode, depending on the electrical characteristics of the tissues, electrode configuration, and application parameters [4]. The small dimensions of the middle ear cavity and the close relationship between the promontory and the cochlea raise concerns about possible thermal or electrical injury during monopolar activation. In middle ear surgery, bleeding may occasionally impair visualization of the operative field, particularly when conventional hemostatic techniques are insufficient. Although monopolar electrocautery may offer a potential means of controlling a localized bleeding source, its effects on cochlear structures require further investigation.

In the present experimental study, monopolar electrocautery was applied transtympanically to the promontory of rats at three different power settings (5, 10, and 20 W) for a standardized duration of 2 seconds. Auditory function was evaluated using distortion product otoacoustic emissions (DPOAE) and auditory brainstem responses (ABR) before the intervention and on days 7 and 14. According to the reported statistical comparisons, no significant differences in DPOAE amplitudes or ABR thresholds were identified across the assessment periods in any of the experimental groups. Similar findings were observed in the untreated control group. These observations suggest that a single brief application under the investigated conditions was not associated with detectable short- term deterioration in the measured auditory parameters. However, the absence of statistically significant differences should not be interpreted as definitive evidence that monopolar electrocautery does not cause cochlear injury.

Galy-Bernadoy et al. [5] investigated the application of monopolar electrocoagulation to the ossicles during middle ear reconstruction using bone cement. Successful ossicular chain reconstruction with bone cement requires appropriate preparation of the ossicular surfaces, including removal of the mucosal covering, to facilitate adherence of the cement. The investigators described the use of monopolar electrocoagulation to remove the mucosa and prepare the ossicular surface before cement application. Their study included six revision stapes procedures and seven partial ossiculoplasties. Audiometric outcomes demonstrated improvement in postoperative air– bone gaps, and no complications related to the technique were reported during the study's follow-up period. These findings suggest that carefully controlled monopolar electrocoagulation may have a role in selected middle ear reconstructive procedures.

Although the findings reported by Galy-Bernadoy et al. [5] are relevant to the present investigation, important differences exist between the two studies. Their technique involved electrocoagulation of the ossicles to facilitate bone cement application, whereas our experimental procedure consisted of direct monopolar electrocautery application to the promontory, which overlies the cochlea. Furthermore, our study investigated three power settings, including 10 and 20 W, and incorporated objective electrophysiological and otoacoustic measurements. DPOAE recordings provide information related to cochlear outer hair cell function, while ABR measurements allow assessment of auditory responses along the peripheral and brainstem auditory pathways. Although neither method demonstrated statistically significant deterioration during the study period, the differences in application sites, exposure conditions, and outcome measurements prevent direct equivalence between the investigations. Additional clinical and experimental evidence is necessary before these observations can be translated into recommendations for middle ear surgery.

The possibility of unintended tissue injury associated with electrosurgical instruments has been discussed in previous investigations. Sankaranarayanan et al. [6] reviewed commonly used surgical energy devices and emphasized the importance of understanding their operating principles and potential complications. Similarly, Townsend et al. [7] investigated unintended electrical energy transfer during monopolar electrosurgery and demonstrated the relevance of instrument positioning and electrical interactions to the risk of thermal injury. Although these investigations were not conducted specifically in middle ear surgery, they illustrate that the effects of monopolar electrocautery depend on factors beyond the selected power setting. Therefore, the findings of our study should be interpreted within the specific experimental conditions rather than generalized to different surgical applications.

Previous otological investigations have predominantly examined the potential effects of monopolar electrocautery on cochlear implant devices. Jeyakumar et al. [1] assessed monopolar cautery application in fresh human cadavers with cochlear implants from different manufacturers. Electrocautery was applied to anatomical regions including the tongue and abdomen, with power settings reaching 50 W and an exposure duration of up to 30 minutes. The investigators measured intracochlear perilymph temperature and evaluated implant integrity before and after electrocautery. No

measurable increase in cochlear temperature or evidence of implant malfunction was identified under the investigated conditions.

In a subsequent cadaveric study, Jeyakumar et al. [2] evaluated different electrosurgical modalities, including bipolar electrocautery, monopolar coagulation, and monopolar cutting, at power settings ranging from 50 to 100 W. Applications were performed on the ipsilateral pectoralis major and temporalis muscles. Despite electrical exposure, implant integrity testing and subsequent device analysis did not identify detectable damage. Additionally, Tien et al. [3] described two patients with cochlear implants who underwent surgical procedures involving monopolar electrocautery without apparent postoperative implant dysfunction. Although these studies provide information regarding the effects of electrosurgical energy on cochlear implant systems, their findings primarily concern implant integrity and do not directly establish the biological effects of electrocautery applied to the cochlear promontory.

In contrast to studies involving cochlear implants or electrocautery applied at distant anatomical sites, our study directly investigated promontory exposure in living animals. Nevertheless, comparisons between these experimental approaches should be made cautiously. Differences in anatomy, body size, electrical current pathways, tissue properties, and electrode placement may substantially influence the distribution of electrical and thermal energy. Furthermore, the absence of direct intracochlear temperature measurements in our study prevents conclusions regarding the magnitude of thermal exposure experienced by cochlear tissues.

Histopathological examination was performed after completion of the audiological follow-up to investigate possible morphological alterations in cochlear structures. The cochleae of animals in the experimental and control groups were evaluated using conventional hematoxylin and eosin staining. No nuclear degeneration or nuclear loss was observed in the examined hair cells, and neither hydropic degeneration nor nuclear loss was identified in spiral ganglion cells or cochlear nerve fibers. The overall morphology of the examined cochlear structures was comparable among the groups. These findings were consistent with the absence of statistically significant changes in the reported audiological measurements.

However, conventional light microscopy has limitations in identifying subtle cellular and ultrastructural abnormalities. Although no overt histopathological alterations were observed, this does not exclude damage at the level of individual hair cell structures, synaptic connections, or other microscopic components of the auditory system. More detailed investigations using electron microscopy, immunohistochemical techniques, or quantitative cellular analyses would provide additional information regarding possible subclinical cochlear injury.

The principal strengths of the present study include the evaluation of three different monopolar electrocautery power settings, the use of objective auditory measurements covering high frequencies, and the combination of functional assessments with histopathological examination. The inclusion of an

untreated control group and repeated audiological measurements at baseline and during follow-up also allowed auditory findings to be examined over the observation period.

Several limitations should be acknowledged. First, the experimental protocol involved a single 2- second electrocautery application. Consequently, the findings cannot be extrapolated to prolonged activation or repeated applications that may be required during more extensive surgical bleeding. Second, audiological follow-up was limited to 14 days, preventing evaluation of delayed or progressive auditory injury. Third, histopathological assessment was performed using conventional light microscopy without electron microscopic or immunohistochemical examination. Fourth, the relatively small number of animals in each group may have limited the ability to identify subtle differences in auditory outcomes. In addition, direct measurements of promontory or intracochlear temperature were not obtained, preventing an assessment of the relationship between delivered electrosurgical energy and cochlear temperature changes. Finally, because this investigation was performed in rats, anatomical and physiological differences between experimental animals and humans limit its direct clinical applicability.

Future experimental investigations should evaluate longer or repeated electrocautery applications, include direct monitoring of cochlear temperature, and incorporate extended audiological follow-up together with more sensitive histopathological techniques. Such investigations may help clarify the relationship between monopolar electrocautery exposure parameters and potential cochlear injury.

Overall, the present findings provide preliminary experimental information regarding the short-term audiological and histopathological effects of direct monopolar electrocautery application to the promontory. Although no significant changes in the measured auditory parameters or overt cochlear morphology were identified under the investigated conditions, further studies are required before the clinical safety of monopolar electrocautery near the cochlea can be established.

Conclusions

In the present experimental study, the short-term effects of monopolar electrocautery applied directly to the promontory were investigated using audiological and histopathological assessments in a rat model. A single 2-second application at power settings of 5, 10, or 20 W was not associated with statistically significant changes in DPOAE amplitudes or ABR thresholds during the 14-day observation period, according to the reported analyses. Furthermore, conventional hematoxylin and eosin examination revealed no overt morphological abnormalities in the evaluated cochlear structures.

These findings provide preliminary experimental evidence regarding the short-term effects of monopolar electrocautery applied to the promontory under the investigated conditions. However, the absence of statistically significant changes does not establish the clinical safety of this technique. Further studies involving repeated or prolonged electrocautery applications, longer audiological follow-up, direct cochlear temperature measurements, and more sensitive histopathological methods are required before these findings can be extrapolated to human middle ear surgery.

Abbreviations

ABR: Auditory brainstem response

DPOAE: Distortion product otoacoustic emission

EDTA: Ethylenediaminetetraacetic acid

H&E: Hematoxylin and eosin

IHS: Intelligent Hearing Systems

SPSS: Statistical Package for the Social Sciences

Declarations

Author Contribution

R.D. contributed to the study design, data analysis and interpretation, and revision of the manuscript. I.C. contributed to data collection and drafting of the manuscript. M.B., O.G., and M.S.A. contributed to data collection. M.F.O. and S.B.E. contributed to drafting of the manuscript. O.O. and E.S. contributed to revision of the manuscript. All authors reviewed and approved the final manuscript.

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Figures

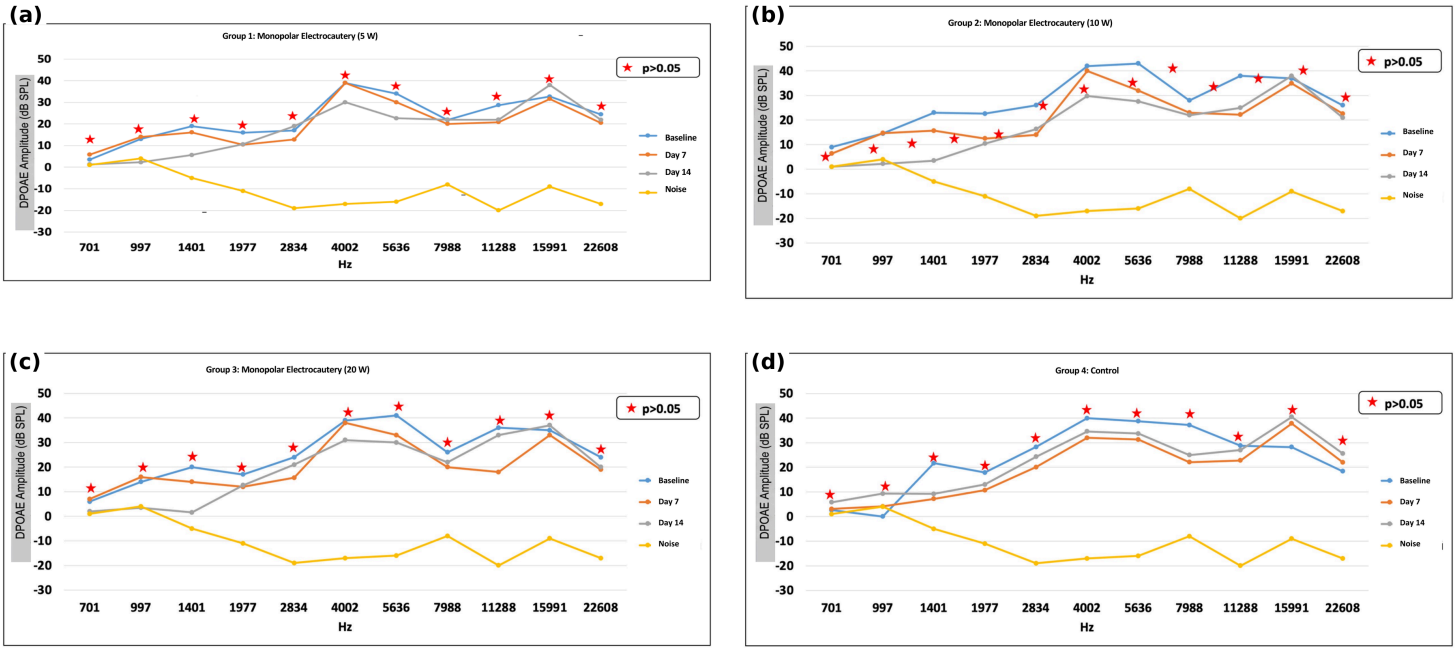


Figure 1

DPOAE amplitude measurements obtained at baseline and at the postoperative follow-up assessments on days 7 and 14. The four panels illustrate the results according to electrocautery exposure: (a) 5 W, (b) 10 W, (c) 20 W, and (d) untreated control group.

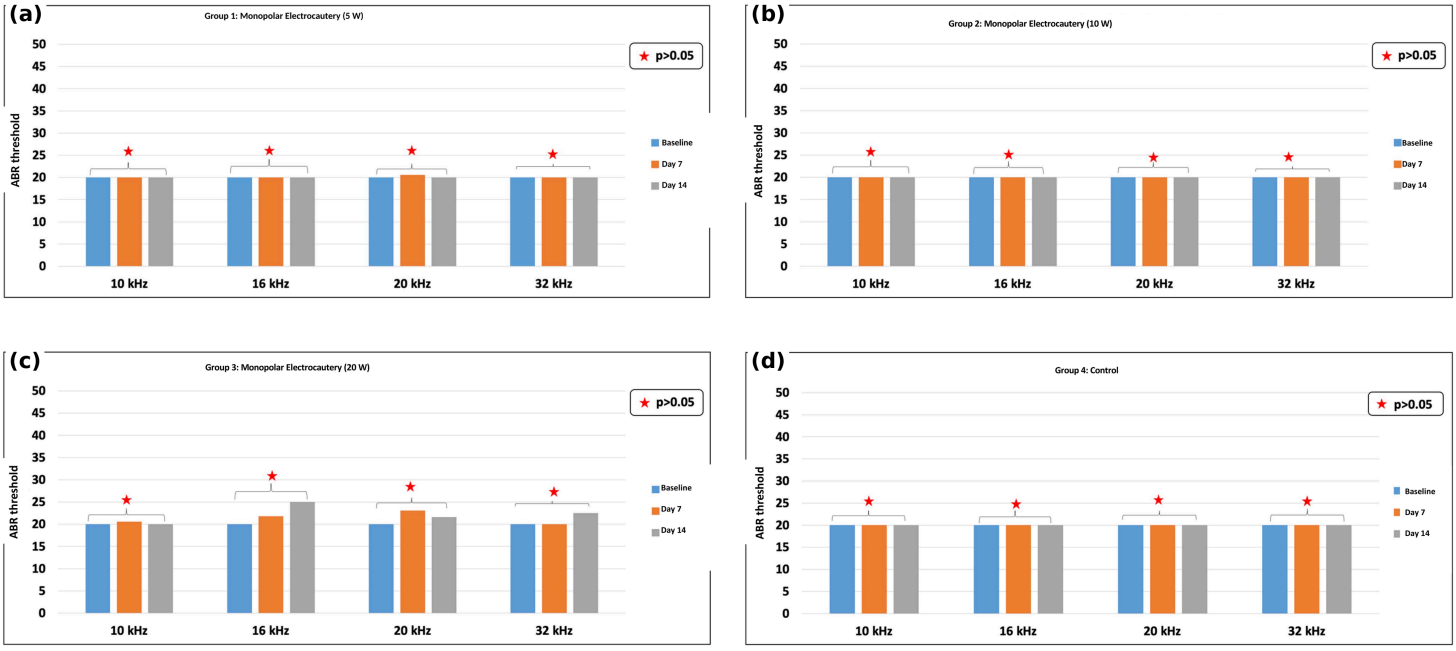


Figure 2

ABR thresholds measured before electrocautery application and during the subsequent 14-day observation period. Measurements from days 7 and 14 are displayed alongside baseline values for each group: (a) 5 W, (b) 10 W, (c) 20 W, and (d) control.

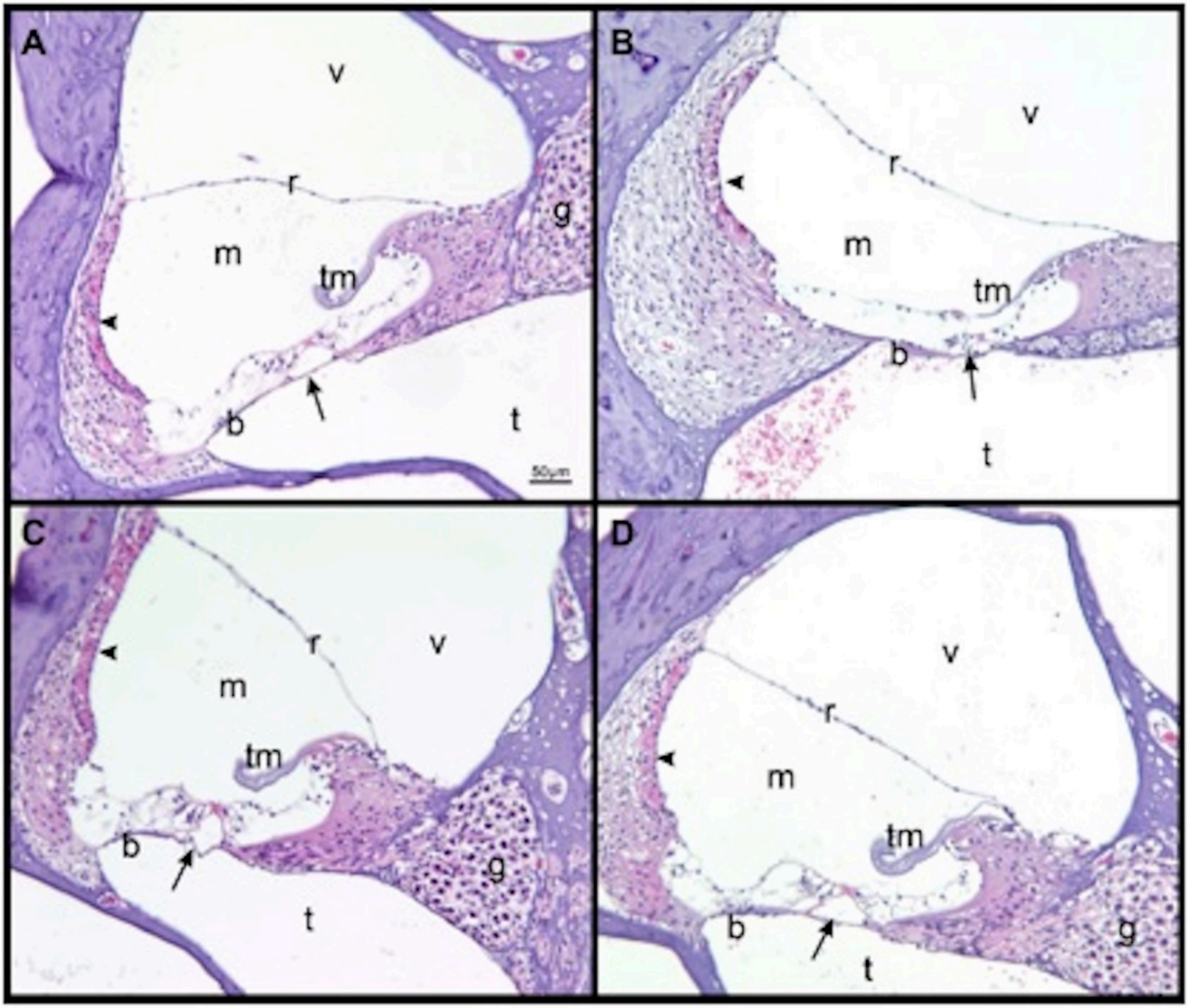


Figure 3

Histological appearance of the cochlea in the experimental groups following hematoxylin and eosin staining. Sections from untreated animals (A) are presented alongside those exposed to monopolar electrocautery at 5 W (B), 10 W (C), and 20 W (D). The scala media (m) is bordered by Reissner's membrane (r) and the basilar membrane (b), separating it from the scala vestibuli (v) and scala tympani (t), respectively. Additional structures identified in the sections are the stria vascularis (arrowhead), organ of Corti (arrow), tectorial membrane (tm), and spiral ganglion (g). The examined structures show no overt morphological alterations among the groups. Scale bar: 50 µm.