Optimal microwave settings for porcine cataract formation for Wet Lab Training

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ABSTRACT

Objective: The objective of this study was to determine the optimal microwave power in watts (w) and time in seconds (s) needed to form a visually significant cataract in fresh *ex vivo*, cadaveric, porcine eyes that can serve as a low-cost, surgical model for trainees.
Methods: Twenty-four fresh, cadaveric, porcine globes were tested. Sets of eight globes were individually microwaved at 1000w, 500w and 100w, the first eye for a time of 3s followed by subsequently adding 1s more for each additional eye up to 10s. The corneas and lenses were then surgically harvested, and the opacification of each was objectively graded using a Pelli-Robson contrast sensitivity chart on a log unit scale of 2.30 (transparent) to 0.00 (total opacification). Lens hardening was subjectively graded on a scale of soft, medium, hard, and scarred.
Results: At 1000w, lens opacification became significant beginning at 5s and hardening took place by 8s. At 500w, lens opacification became significant at 6s and hardening took place at 8s but quickly transitions to scarring by 9s. At 100w, significant lens opacification and hardening did not occur by 10 seconds. The cornea remained transparent at all parameters, except for a trend toward opacification at 500w after 9s.
Conclusion: Optimal settings for microwaving fresh, cadaveric porcine eyes were found to be 1000w for 5 to 10s. These settings induced fully opacified cataracts with a range of soft to hard lenses without leading to severe scarring of the lens-capsule complex or visually significant corneal opacification.

Key words: Porcine eye, Cataract model, Microwave induced cataract, Cataract surgery, Surgical training, Capacity building

INTRODUCTION

Cataracts are the leading cause of blindness worldwide, affecting 94 million people worldwide[1]. Cataracts have a greater burden in low-resource settings, contributing to a greater proportion of vision loss and blindness than in higher-resource settings[1]. In order to alleviate this burden, increased access to high-quality cataract surgery conducted by well-trained ophthalmic surgeons is needed. Successful surgery has the potential to increase eye care utilization as surgical recipients can become community champions[2,3]. These individuals can encourage other affected individuals to seek out ophthalmologic care, starting with those closest to them in their homes and neighborhoods[2-4]. Family members of patients can also serve as powerful advocates, testifying to the notable improvement in function and activities of daily living[4,5].

Surgical simulation through wet lab experiences allows trainees to practice fine motor skills, rehearse surgical steps, and gain a tactile understanding of instrument utilization[6]. The Accreditation Council for Graduate Medical Education considers surgical simulation training an essential part of ophthalmology resident training[6,7]. As only the operating surgeon can experience the fine balance of hand-eye coordination, micromovement in all three-dimensional planes, and visualization through a surgical microscope, wet labs have great utility in improving operating room performance and provide a setting for assessment and feedback from faculty[7].

Different models can be used for wet labs including animal eye models, synthetic models, and human cadaveric eyes (considered the best for training). However, *ex vivo* animal globes stand out as simple, accessible, and cost-effective models, especially in regions with active animal farming industries. The use of *ex-vivo* porcine globes as models for cataract surgery has been documented in the literature since as early as the 1990s with lens opacification induced through different methods including chemically, using formalin or formaldehyde, or electromagnetically using microwave energy[7-10]. Microwaves are increasingly accessible around the globe and are available in many training institutes and teaching hospitals in Low and Middle-Income Countries (LMIC). While microwave energy for cataract induction has been previously described, our purpose was to identify optimal microwave settings (power, in watts, and time, in seconds) for the opacification of porcine lenses without visually significant opacification of the corneas, with a focus on simple, reproducible strategies.

MATERIALS AND METHODS

Porcine globes were sourced from Sierra for Medical Science Ltd. The fresh globes were harvested within 48 hours of study use and kept cool via ice and refrigeration but never frozen. We utilized a simple microwave, built for kitchen capacity (Fridgidaire LFMV1846VFA model). Globes were excluded if lens opacification or visually significant corneal haze was noted subjectively. Qualifying cadaveric, porcine eyes were debrided of orbital fat and muscle tissue, to control for variations in the harvesting technique of the globes used by the butchers. To determine our time range of focus, six globes were exposed to 1000w of microwave energy until globe explosion was observed. This occurred around 12 seconds, allowing us to set our upper limit of microwave exposure time to 10 seconds. Twenty-four globes were randomly separated into three groups of eight globes. Eight eyes were individually microwaved at 1000w, the first eye for a time of 3 seconds followed by subsequently adding 1 second more for each additional eye up to 10 seconds for a total range of 3 to 10 seconds. These microwave exposure times were repeated for another eight eyes at 500w and another eight eyes at 100w.

Following microwave treatment, the corneas and lenses of each globe were surgically harvested. The opacification of each tissue was graded objectively using a small Pelli-Robson contrast sensitivity chart by placing each cornea and each lens over the chart letters. The highest contrast letter was assigned a value of 0.05 log units. The lowest contrast letter was assigned a value of 2.30 log units. When a letter could no longer be read through the tissue, a grade was assigned ranging from 2.30 (totally transparent) to 0.00 (totally opacified) log units. Lens hardening was subjectively graded by touch on a scale of soft, medium, hard, and scarred.

This project meets ethical requirements for investigation using cadaveric animal tissues. Since no human tissues or subjects were utilized in this project Institutional Review Board approval was not required. All porcine tissue was acquired from Sierra for Medical Science which is a compliant, United States Department of Agriculture approved source for biological tissues for research. Since all tissues were from slaughterhouses, no animals were harmed solely for the purpose of this research.

RESULTS

The opacification of lenses and corneas for globes microwaved at the three different powers over time are shown in Figures 1 and 2, respectively. At 1000w, lens opacification becomes significant beginning at 5s and hardening takes place by 8s. At 500w, lens opacification becomes significant at 6s and hardening takes place at 8s but quickly transitions to scarring by 9s. At 100w, the lenses did not achieve substantial opacification or hardening by ten seconds of microwave exposure. With regards to the corneas, the globes microwaved at 100w and 1000w were able to maintain relative transparency of the corneas (Pelli-Robson score of > 1.5 log units) when exposed to up to ten seconds of microwave treatment. In the 500W group, significant opacification of the corneas was seen at exposure times greater than eight seconds. Pelli-Robson scores and lens hardness grades are shown in Table 1.

Figure 1: Opacification scores for lenses microwaved at 1000w, 500w, and 100w over 3-10 seconds, graded on a Pelli-Robson contrast sensitivity chart with a scale of 2.30 log units (transparent) to 0.00 log units (total opacification**)**

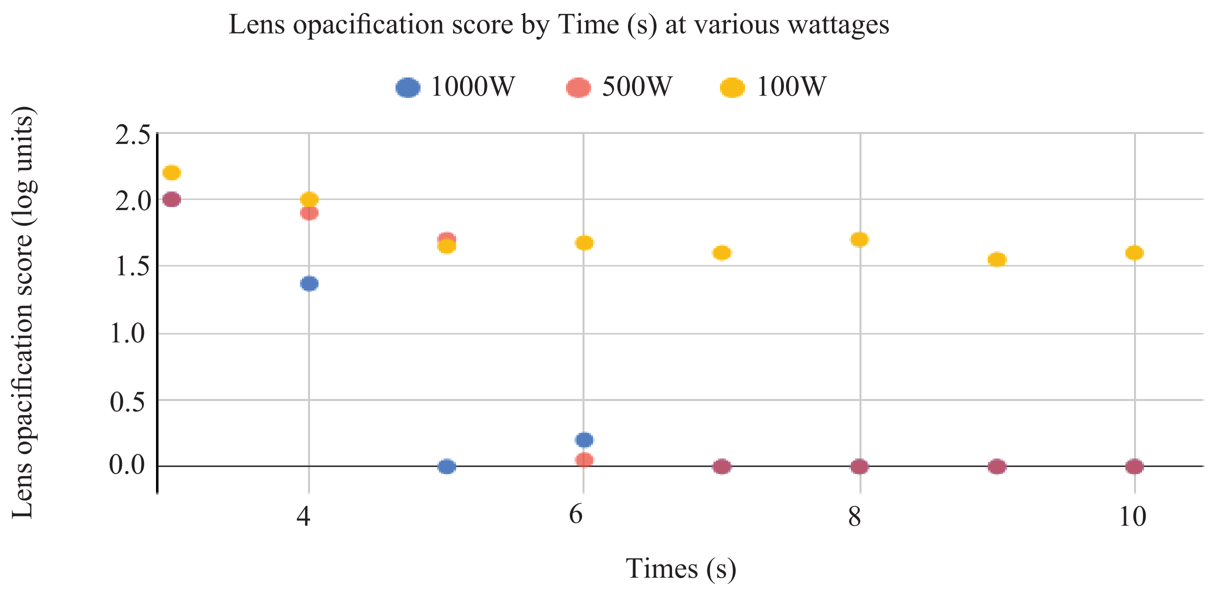

Figure 2: Opacification scores for corneas microwaved at 1000w, 500w, and 100w over 3-10 seconds, graded on a Pelli-Robson contrast sensitivity chart with a scale of 2.30 log units (transparent) to 0.00 log units (total opacification)

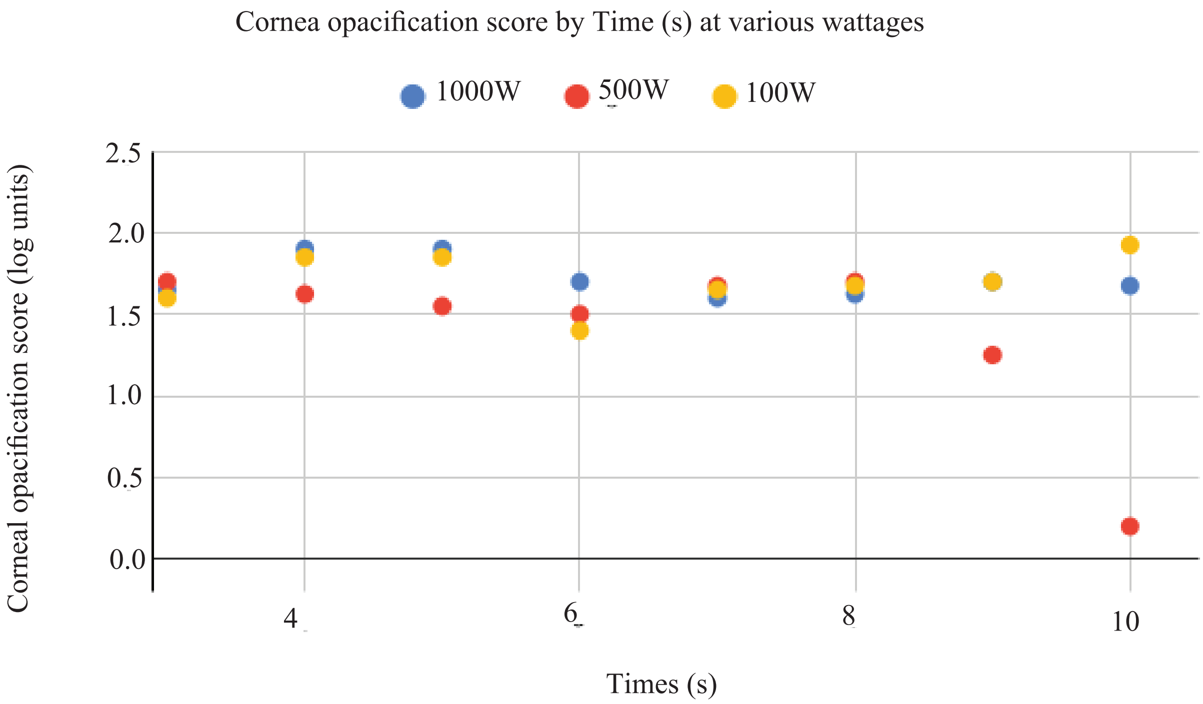

Figure 3: Opacified cornea and lens on Pelli-Robson contrast sensitivity chart

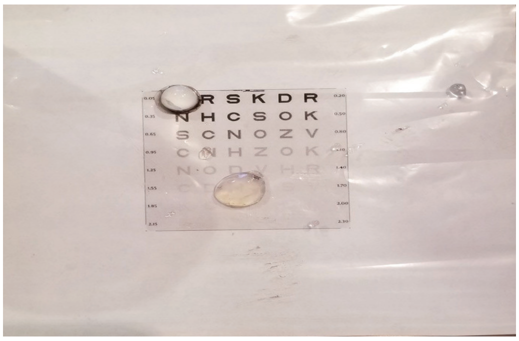

Table 1: Lens hardness grade for porcine globes

Eye	Power (W)	Time (S)	Microwave Freq. (MHz)	Lens Hardness Grade
1	1000	3	Done	Soft
2	1000	4	Done	Soft
3	1000	5	Done	Medium
4	1000	6	Done	Soft
5	1000	7	Done	Soft
6	1000	8	Done	Hard
7	1000	9	Done	Hard
8	1000	10	Done	Hard
*	1000	12	Explosion	
9	500	3	Done	Soft
10	500	4	Done	Soft
11	500	5	Done	Soft
12	500	6	Done	Soft
13	500	7	Done	Soft
14	500	8	Done	Hard
15	500	9	Done	Scarred
16	500	10	Done	Scarred
17	100	3	Done	Soft
18	100	4	Done	Soft
19	100	5	Done	Soft
20	100	6	Done	Soft
21	100	7	Done	Soft
22	100	8	Done	Soft
23	100	9	Done	Soft
24	100	10	Done	Soft

DISCUSSION

The purpose of this study was to determine the optimal microwave power in watts (w) and time in seconds (s) needed to form a cataract in fresh cadaveric, porcine eyes that can serve as a low-cost, surgical model for trainees in LMICs. Based on our findings, we recommend microwaving *ex-vivo*, fresh, cadaveric porcine globes at 1000w for 5 to 10s as it provides fully opacified cataracts with a range of soft to hard lenses without leading to severe scarring of the lens-capsule complex or visually significant corneal opacification. Porcine globes are more human-like in size than cow globes giving them an intrinsic advantage for surgical trainees[11]. While porcine globes in our study came from an approved supplier for medical research, we feel porcine globes harvested from any local butcher who slaughters animals in a humane way is an ethical source of fresh tissue for use in wet lab.

Study limitations

Limitations of this study include transferability in light of the intrinsic variation between microwaves and globes. We attempted to control for this as much as possible by assessing various wattages of a typical domestic microwave and by debriding the globes of fat and muscle prior to microwaving. Another limitation was that only subjective assessment of the clarity of each lens and cornea was performed prior to microwaving. Objective assessment was only done after microwaving due to our grading method. This could allow bias to impact the results if the starting clarity of individual eyes was significantly different at baseline. Lens hardening was graded subjectively by touch. A more objective method would improve future studies.

CONCLUSION

In conclusion, microwaving fresh, cadaveric porcine eyes at 1000w for 5 to 10s provides fully opacified cataracts with a range of soft to hard lenses without leading to severe scarring of the lens-capsule complex or visually significant corneal opacification. Using these identified optimal settings as a starting point, this model can be replicated in wet lab training centers anywhere were fresh porcine eyes and microwaves are available.

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