







Microdroplet and spatter contamination during phacoemulsification cataract surgery in the era of COVID-19

Charles N. J. McGhee DSc FRCOphth^{1,2,3}  | Simon Dean MSc FRANZCO^{1,3} |
Simone E. N. Freundlich MBChB^{1,2}  | Akilesh Gokul BOptom(Hons) PhD^{1,2}  |
Mohammed Ziaei MD FRCOphth^{1,2} | Dipika V. Patel PhD MRCOphth^{1,2}  |
Rachael L. Niederer PhD FRANZCO^{1,2}  | Helen V. Danesh-Meyer PhD FRANZCO^{1,2,3} 

¹Department of Ophthalmology, New Zealand National Eye Centre, Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand

²Department of Ophthalmology, Greenlane Clinical Centre, Auckland District Health Board, Auckland, New Zealand

³Eye Institute, 123 Remuera Road, Auckland, New Zealand

Correspondence

Professor Charles N. J. McGhee,
Department of Ophthalmology, Faculty of
Medical and Health Sciences, University
of Auckland, New Zealand.
Email: c.mcgee@auckland.ac.nz

Abstract

Importance: Determine phacoemulsification cataract surgery risk in a Covid-19 era.

Background: SARS-CoV-2 (Covid-19) transmission via microdroplet and aerosol-generating procedures presents risk to medical professionals. As the most common elective surgical procedure performed globally; determining contamination risk from phacoemulsification cataract surgery may guide personal protection equipment use.

Design: Pilot study involving phacoemulsification cataract surgery on enucleated porcine eyes by experienced ophthalmologists in an ophthalmic operating theatre.

Participants: Two ophthalmic surgical teams.

Methods: Standardized phacoemulsification of porcine eyes by two ophthalmologists accompanied by an assistant. Fluorescein incorporated into phacoemulsification irrigation fluid identifying microdroplets and spatter. Contamination documented using a single-lens reflex camera with a 532 nm narrow bandpass (fluorescein) filter, in-conjunction with a wide-field blue light and flat horizontal laser beam (wavelength 532 nm). Quantitative image analysis using Image-J software.

Main Outcome Measures: Microdroplet and spatter contamination from cataract phacoemulsification.

Results: With phacoemulsification instruments fully within the eye, spatter contamination was limited to <10 cm. Insertion and removal of the phacoemulsification needle and bimanual irrigation/aspiration, with irrigation

active generated spatter on the surgeons' gloves and gown extending to >16 cm below the neckline in surgeon 1 and > 5.5 cm below the neckline of surgeon 2. A small tear in the phacoemulsification irrigation sleeve, presented a worst-case scenario the greatest spatter. No contamination above the surgeons' neckline nor contamination of assistant occurred.

Conclusions and Relevance: Cataract phacoemulsification generates microdroplets and spatter. Until further studies on SARS-CoV-2 transmission via microdroplets or aerosolisation of ocular fluid are reported, this pilot study only supports standard personal protective equipment.

KEYWORDS

aerosol-generating procedure, Covid-19, microdroplet generating procedure, phacoemulsification cataract surgery, SARS-CoV-2

1 | INTRODUCTION

Globally, phacoemulsification cataract surgery is the most frequently performed elective surgical procedure.¹ Since the emergence of SARS-CoV-2 (Covid-19), experience with earlier coronaviruses (eg, SARS-CoV-1, MERS) has prompted ophthalmologists to question transmission risks between patients and health-care workers during aerosol and microdroplet generating procedures, specifically phacoemulsification and vitrectomy.²⁻⁷ Elsewhere, concerns have been raised by specialties utilizing ultrasonic equipment and the appropriate level of protective equipment required by health professional during a time of both symptomatic and asymptomatic Covid-19 transmission.^{4,8-14}

Furthermore, knowledge of ocular tropism of viral agents is well-recognized, with several existing viruses (including SARS-CoV-1) isolated in the tear film, cornea, aqueous humour and crystalline lens.^{6,15-19} As SARS-CoV-2 has demonstrated both an extended incubation period between 2 and 14 days in patients, high rates of asymptomatic carriers and extended surface stability with a half-life >5 hours on steel and plastic, there appear to be multiple opportunities for virus transmission within health settings.^{14,20-23} Although SARS-CoV-2 RNA has been identified both in tears and exhaled air samples where symptomatic COVID-19 patients have been treated, no viable virus has been recovered from the tear film therefore the risk of transmission by this route currently appears to be low.^{19,24-26} In addition to the unique viral characteristics that SARS-CoV-2 exhibits; piezosurgical procedures in maxillofacial, dental and orthopaedic surgery have demonstrated significant aerosol, microdroplet and spatter generation resulting in contamination of the surgeon, assistant and surgical field.⁸⁻¹⁰ During phacoemulsification cataract/lens surgery,

piezoelectric crystals convert electrical energy into mechanical energy-producing ultrasonic vibration of a titanium phacoemulsification needle.¹¹ Emulsified lens is aspirated through the hollow needle, while pressurized irrigation in a surrounding sleeve maintains the anterior chamber, and cools the needle and surrounding tissue.¹¹ The purpose of this pilot study was to assess the extent of micro-droplet generation and spatter distribution during simulated phacoemulsification cataract surgery on porcine lens and provide insight into required personal protective equipment (PPE) use during cataract surgery.

2 | METHODS

Experiments were performed in a fully functioning ophthalmic theatre in a tertiary teaching hospital in Auckland, New Zealand. Experiments utilized porcine eyes (N = 5) mounted in an ophthalmic mannequin head, positioned and draped using an ophthalmic non-absorbable plastic drape. Experiment 1 used a superior corneal approach to a left eye to maximize visualization and primarily assess the generation of micro-droplets. In Experiments 2 and 3, to assess contamination of surgical team and field, the surgeon performed the experiments seated on the "patient's" right (temporal approach) with the assistant, instrument table and phacoemulsification device, to the left side as per standard procedures.

PPE included sterile surgical gown and gloves, with and without a standard surgical mask and clear protective eyeglasses. Two attending ophthalmic surgeons participated, one male (surgeon 1; height-189 cm) and one female (surgeon 2; height 157 cm). A single phacoemulsification device (Stellaris Elite, Bausch & Lomb, Rochester, New York, New York) was used with the following settings; bottle height 90 to 95 cm,

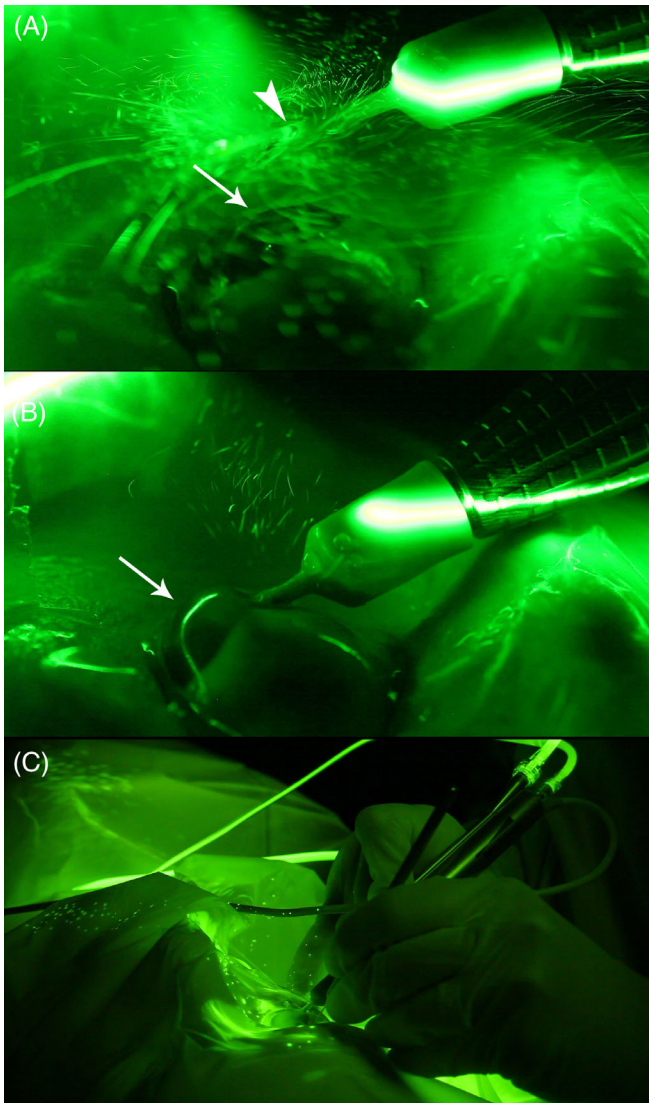


FIGURE 1 A, Illustration of micro-droplets generated from the active phacoemulsification needle (with irrigation on) extending extensively in all directions when tested 1.5 cm above the ocular surface (arrow-head, phacoemulsification needle tip, arrow, corneal apex). B, Less marked micro-droplet generation with the active phacoemulsification needle within the porcine eye during simulated phacoemulsification (arrow, corneal apex). C, Local fluorescein stained spray and spatter on drape, instruments and surgeons' gloves during phacoemulsification procedure. (A and B laser light, 532 nm at 10 mW, via an optical grating. C, wide-field blue light illumination with 532 nm narrow bandpass, fluorescein filter)

ultrasound power 40%, vacuum 400 mmHg, pulse 170 per second. Vacuum increased to 600 mmHg during intraocular irrigation aspiration (I/A). In each of five experiments, a new porcine eye was used. Irrigation comprised 400 mL of balanced salt solution (BSS, Alcon Laboratories) incorporating 0.5 mL of Fluorescein (500 mg/5 mL, Novartis), run through the phacoemulsification tubing/instruments.

Following standardized clear corneal incisions, a divide-and-conquer phacoemulsification, procedure was followed by both surgeons. A main, two-step, 2.7 mm wide, clear corneal temporal incision (superior in Experiment 1, temporal in Experiments 2 and 3) and two 1.1 mm paracentesis corneal incisions, each at 90° to the main incision, were created. The anterior chamber was filled with a cohesive viscoelastic and the phacoemulsification needle was inserted using forceps to allow atraumatic corneal entry. The porcine lens was phacoemulsified through three stages; (a) sculpt (90 seconds), (b) segment removal (30 seconds) and (c) bi-manual irrigation/aspiration (I/A) (60 seconds). A second instrument (Barratt mushroom) was introduced through a paracentesis for nuclear manipulation.

Experiment 1 followed the standardized protocol with irrigation flow active when inserting/removing the phacoemulsification needle and I/A (instruments). Experiment 2 followed the standardized protocol with the fluorescein infused irrigation turned off when inserting/removing instruments. Experiment 3 followed the standardized protocol with irrigation turned on when inserting/removing the instruments.

Photographs were obtained with a single-lens reflex camera (Canon 5D MKII full-frame DSLR, fitted with a 50 mm f1.8 lens and 532 nm narrow bandpass (fluorescein) filter. In Experiment 1, illumination was laser light (532 nm at 10 mW) via an optical grating to produce a flat horizontal beam (camera barrier filter removed). Illumination in Experiments 2 and 3, utilized wide-field blue light illumination (18×10W RGBW LED PAR stage light, Guangzhou Aicheng Technology, China) to provide the highest contrast to capture Fluorescein contamination of the surgical field.

Photographs of surgeon PPE (surgical gown, gloves, neck, mask and eye protection); assistant PPE, instrument tray, microscope and floor beneath the operating area were taken before, during and at the end of Experiments 2 and 3. Experiments were simultaneously recorded by the internal microscope video camera.

Spatter on PPE was quantitatively analysed using Image-J software (National Institutes of Health, New Zealand). Each image was converted to greyscale format. A binary image was then produced by manual thresholding. Particle number, and area (pixels²) were determined using the “analyse particles” command.

3 | RESULTS

Each experiment lasted approximately 20 minutes. Calibration established a maximum level of resolution of

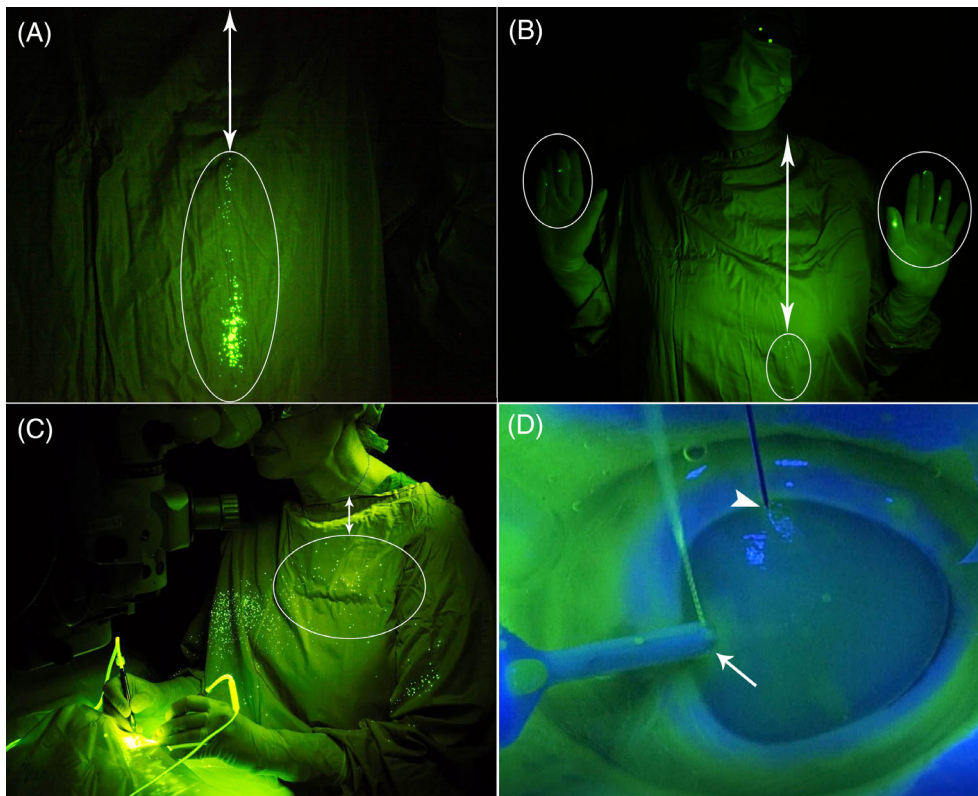


FIGURE 2 A, Maximal contamination of lower chest area (circled) of gown on Surgeon 1 Experiment 2, approximately at the level of porcine eye when seated, and >16 cm from the gown neckline (double-headed arrow). B, Contamination of lower chest area of gown and gloves (circled) on Surgeon 2 Experiment 3 and >21 cm from the gown neckline (double-headed arrow). C, Greatest contamination on upper arms and chest (circled) of surgical gown on Surgeon 2 Experiment 2 related to a small defect/tear subsequently noted in distal phacoemulsification needle sleeve. Spatter on chest >5.5 cm below the gown neckline (double-headed arrow) with a single spatter point 2.4 cm from neckline. D, Operating microscope video frame-grab showing vertical spray of micro-droplets from phaco-tip (arrow) as it re-enters the main corneal incision in the experiment illustrated in C (arrow-head highlights second instrument in corneal paracentesis with no fluid leak). (All images wide-field blue light illumination with 532 nm narrow bandpass, fluorescein filter in A, B and C)

TABLE 1 The number of particles and stained spatter area on the surgeon's gown during phacoemulsification by surgeons 1 and 2 under two experimental conditions (Experiment 2 irrigation off, Experiment 3 irrigations on, when inserting of phacoemulsification instruments into eye)

Phacoemulsification gown spatter	Number of particles	Area stained (pixels ²)
Surgeon 1 Experiment 2	95	29 207
Surgeon 1 Experiment 3	270	70 327
Surgeon 2 Experiment 2	422*	44 903
Surgeon 2 Experiment 3	28	949
Mean ± SD	204 ± 178	36 347 ± 29 051

Note: Data highlight significant variation in the number of spatter particles (28-422) and area stained. *(In Experiment 2 Surgeon 2 a small tear was noted in the distal phacoemulsification needle sleeve at the end of the experiment).

between 89 and 27 μm in Experiments 1 and 2, respectively, with smallest the microdroplet/spatter imaged being 440 and 77 μm respectively. Therefore,

unfortunately, Experiment 1 did not produce sufficient resolution to capture aerosolisation (elements <20 μm if present) during phacoemulsification of the porcine lens. However, phacoemulsification created significant microdroplet formation but with needle and bimanual I/A instruments fully within the eye, the generation of spatter and micro-droplets was modest and limited to <10 cm from the eye (Figure 1). However, on insertion and removal of surgical instruments from the eye, spatter and micro-droplets were more common/extensive on surgical gowns and surgical drapes. Spatter and microdroplet contamination of surgeons' gloves and gown in Experiments 2 and 3 occurred in all four procedures, however, there was no evidence of fluorescein spatter on the neck, face, mask, glasses or surgical cap.

Contamination of surgical gowns was also variable across the two surgeons, in Surgeon 1 (taller) spatter landed >16 cm below the gown neckline and while in Surgeon 2 (shorter) typically landed >5.5 cm below the gown neckline (with the exception of one single spatter point identified 2.4 cm from neckline in the experiment



with the irrigation sleeve tear) (Figure 2). No fluorescein contamination was identified on the assistant or the instrument table, however, spatter was identified on the subjacent floor, the surgical drape and underside of microscope.

Notably, in the latter part of Experiment 2 and Surgeon 2, a small tear was identified in the distal irrigation sleeve surrounding the phacoemulsification needle, associated with greater gown spatter (Figure 2) and the greatest extent of drape contamination (33 cm). This may represent the “worst-case scenario” for routine phacoemulsification*. (Table 1).

4 | DISCUSSION

As with previous experiments demonstrating piezosurgical procedures in maxillofacial and dentistry,^{10,12} simulation of phacoemulsification using fluorescent markers produced spatter contamination on multiple surgical surfaces including gloves, gowns, patient drape, operating floor and microscope undersurface. The results confirm the potential for significant spatter contamination of both surgical surfaces and PPE due to generation of micro-droplets during phacoemulsification cataract surgery, in particular when irrigation was active when inserting/removing the phacoemulsification needle and I/A into the eye. Furthermore, a small tear in the distal phacoemulsification irrigation sleeve (a not uncommon occurrence) markedly increased spatter in one experiment. Proximity of the surgeon to the eye that is, lesser height/shorter arm length may also predispose to spatter nearer to the neck and face.

These observations suggest that in Covid-19 positive patients, there is a theoretical risk that phacoemulsification surgery associated with pressurized irrigation may present a contamination and transmission risk, similar to simulations in dental, maxillofacial and orthopaedic surgery.⁸⁻¹⁰ Nonetheless, encouragingly this pilot study demonstrated minimal micro-droplet generation when instruments were inserted into the eye with the irrigation off and when the phacoemulsification hand piece was functioning within the eye. Reassuringly, spatter did not extend above the neckline of the surgeons' scrub gown; sparing the surgeons' head, surgical mask and eyewear nor did spatter contaminate the assistant or equipment table. We therefore conjecture through our observed locally-limited microdroplet spatter and in the context of a lack of convincing evidence of viable SARS-CoV-2 in the tear film,^{19,24,25} that the risk of contamination is relatively low and only standard PPE equipment is

required for the operating surgeon, assistant and the circulating theatre staff.

Limitations of this pilot study include: the small number of experiments performed limiting wider generalisability; occurrence of a worst-case scenario due to a small tear in a phacoemulsification sleeve during one experiment; generalisability of the results to the human crystalline lens when the experiments were conducted on porcine lenses and the possible generation of spatter from irrigation fluid that did not enter the eye nor come into contact with an ocular surface. While these experiments demonstrated microdroplets and spatter contamination clearly, due to the limit of resolution they were unable to detect aerosol generation during phacoemulsification of a porcine lens. Despite this, previous pilot studies and experiments have demonstrated that piezosurgical procedures can and do produce both microdroplets and aerosolized particles.^{10,12,27} By the nature of clinical and surgical practice, ophthalmologists may be at risk of exposure to SARS-CoV-2.^{5,19,24,28} However, while both microdroplets and exhaled aerosol have been identified as potential routes for SARS-CoV-2 transmission, the risk of viable viral contamination via ocular fluid, through the generation of microdroplets and aerosol during phacoemulsification surgery, appears to be low but is still under investigation.^{4,23,25,26,29}

In the current context of the Covid-19 pandemic with infection rates accelerating at unprecedented speeds, our pilot study results only indicate support for the use of standard surgical PPE during phacoemulsification cataract surgery. Standard PPE includes surgical gown, gloves and mask. The results also indicate that careful management of the contaminated surgical field may be required when removing surgical drapes, cleaning the operating microscope and subjacent floor. Introduction of a transparent, sterile barrier extending around the operating microscope objective might theoretically reduce the degree of surgeon contamination. However, ultimately, PPE must be used as part of a comprehensive approach in the operating room that includes: identifying at-risk patients, physical distancing if possible, frequent hand hygiene and appropriate cleaning and disinfection in the operating environment.

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CONFLICT OF INTEREST

None declared.

ORCID

Charles N. J. McGhee  <https://orcid.org/0000-0001-7048-0706>

Simone E. N. Freundlich  <https://orcid.org/0000-0003-3321-3101>

Akilesh Gokul  <https://orcid.org/0000-0003-0643-9420>

Dipika V. Patel  <https://orcid.org/0000-0001-9994-4631>

Rachael L. Niederer  <https://orcid.org/0000-0002-4311-859X>

Helen V. Danesh-Meyer  <https://orcid.org/0000-0002-9177-003X>

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