Guidelines and Recommendations for Tonometry Use during the COVID‑19 Era

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Abstract:
The novel coronavirus disease COVID‑19 caused by Severe Acute Respiratory Syndrome Coronavirus‑2 (SARS‑CoV‑2) has resulted in a substantial change in eye care and clinical practice. There has been conflicting information and weak evidence on the virus’s transmission through tears. Yet, virus detection on cornea and conjunctiva surface as a gateway for infection is not well‑studied. Moreover, there have been no reported cases of SARS‑CoV‑2 transmission through tonometry to date. Thus, this uncertainty has urged this review on evidence‑based guidelines and recommendations on tonometer use in the COVID‑19 era. The aim of this article is to provide ophthalmologists with recommendations for tonometry practice based on current evidence and best practice guidelines.

Keywords:
COVID‑19, glaucoma, public health measures, tonometry

Introduction

Coronavirus Disease 19 (COVID‑19), caused by the Severe Acute Respiratory Syndrome Coronavirus‑2 (SARS‑CoV‑2), has been declared a pandemic by the World Health Organization on March 11, 2020. The global response to COVID‑19 has resulted in critical changes in clinical practices worldwide to control the spread of the infection.[1]

The era of COVID‑19 has introduced unique challenges for eye care practitioners in terms of minimizing infection risk, yet still identifying patients who are at high risk of losing vision. All health‑care practitioners, including ophthalmologists, bear the responsibility of preventing the transmission of the infection and subsequently decreasing the rate of new case development. General approaches to control infection risk in the ophthalmology setting include virtual consultations when possible, reducing the number of hospital patient visits, use of single‑use instruments, and regular sanitization of equipment and physical distancing have been outlined elsewhere.[2] Tonometry poses a unique challenge in the COVID‑19 era: contact with the ocular surface creates a potential risk of viral transmission, but identifying patients with uncontrollable glaucoma is essential to prevent patients from losing sight over the lockdown period. Delayed appointments and loss of follow‑ups during this time are likely to result in an irreversible visual loss for some patients.[3,4]

The choice of the optimal method of tonometry during this time depends on modalities which offer a low risk of infection, while ensuring patients with uncontrolled intraocular pressure (IOP) are not missed. The aim of this review is to highlight and summarize current guidelines and recommendations pertaining to tonometry use with specific relevance to COVID‑19.

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**Routes of Infection from the Eye and Risk of Infection Through Tonometry**

It seems logical to firstly address the question of whether viral infection from an eye can be transmitted to the tonometer tip or viral particles being released into the surrounding atmosphere from the tonometer. Currently, it seems uncertain, though theoretically possible, that infection from the ocular surface in patients with COVID-19 can be transmitted to other individuals.

Virus infectivity and pathogenicity in ocular tissue has yet to be proven. The virus is mainly transmitted human-to-human through direct contact with secretions from an infected person or through inhalation of droplets containing SARS-CoV-2.\(^5\) One recent case study emerged, suggesting that SARS-CoV-2 can cause follicular conjunctivitis 13 days postonset of the infection and in another virus was isolated in a patient with known COVID-19 infection and conjunctivitis.\(^6\) However, Cheema et al. recently highlighted conjunctivitis as the first sign of viral infection.\(^7\) Several considerations seem to make infection from ocular, rather than respiratory secretions less likely. First, the viral RNA levels in the conjunctiva may be significantly lower than those in the respiratory samples.\(^8\) Second, conjunctivitis seems to be of a shorter clinical duration than systemic illness: in one documented case, the viral load in the conjunctival swab appeared to gradually decrease over the 5-day course of conjunctivitis accompanied by improvement of ocular symptoms.\(^9\) Finally, patients with confirmed COVID-19 infection may not express the virus in their tears. One study of 17 patients failed to identify the virus through culture or PCR following repeated testing over 7–20 days after onset of initial symptoms.\(^1\)

Although the expression of the human angiotensin-converting enzyme-2 (ACE2), used by the virus to gain entry, in more anterior ocular tissues, such as the conjunctiva or cornea was in doubt, it has been described recently by Sungnak et al., who demonstrated that human cornea and conjunctiva express ACE2 receptor and TMPRSS2 protease required for SARS-CoV-2 infection.\(^9\) ACE2 receptor has been recognized as a pathway for SARS-CoV-2 to the entrance to the cell, which subjects hypertensive patients at risk of acquiring this infection,\(^10,11\) and has been reported in aqueous humor.\(^12\) It has been speculated that active secretion by the lacrimal gland, obstruction of the nasolacrimal duct, and positive pressure through respiratory ventilation may all contribute to the isolation of the virus from the conjunctival sac.\(^13,14\)

Although there has been no reported case of SARS-CoV-2 transmission through tonometer tips, the behavior of other viruses\(^15-17\) may offer surrogate, yet the safest evidence for practice in terms of disinfection and reuse of tonometers while acknowledging differences in these viruses from SARS-CoV-2 in terms of their structural biology, vectors, and other factors. These viruses include adenovirus (serotypes 8 and 19), and herpes simplexvirus 1 (HSV 1), which have both been implicated in ophthalmic nosocomial outbreaks related to tonometer applanations tips.\(^15-17\) Adenovirus has been recovered on metal and plastic surfaces nearly 50 days after in vitro inoculation.\(^18\) Although 0.05% hypochlorite solution is likely to be effective in eliminating HSV1 and adenovirus 8,\(^16,19\) the evidence regarding the effectiveness of isopropyl alcohol against adenovirus 8 is conflicting.

With the uncertainty regarding the possibility of exposed ocular surface facilitating as a gateway for acquiring SARS-CoV-2 and the risk of its transmission, it is best to practice extra precautions to lower the risk of transmission.

**General Measures and Considerations**

The majority of patients in glaucoma clinics are typically over the age of 60 years, which is precisely the population that is a high risk of morbidity and mortality from COVID-19. Hence, general measures to reduce infection risk should be instituted. These include a past patient history for influenza-like illness, diarrhea, loss of taste, and smell (anosmia and ageusia), which have been proposed as early manifestations of COVID-19 disease, especially in asymptomatic people.\(^20\) Other general infection control precautions include using personal protective equipment (PPE) such as a mask, gloves, gown, and goggles. Further, all patients should be instructed to wear surgical masks before attending eye clinics. Ophthalmologists should change gloves and PPE between patients as a standard of care and take appropriate actions if exposure to respiratory secretions occurs during an examination or clinical procedures. It is advisable to effectively communicate with institutional infection control practitioners who can provide relevant advice and updates about safe work practices for ophthalmologists.\(^21\)

Disinfection solutions, water soaks, and ultraviolet light can cause varying degrees of damage to tonometer prisms. These include microscopic cracks, dissolution of acrylate glue, warping, and opacification of the prism. Cracks in the tonometer tip may also allow the hollow tip to harbor disinfectants and microbes, which could leach back out during applanation. Thus, all tonometer tips should be inspected to avoid corneal damage and conjunctival irritation.\(^22-28\) In addition, we recommend disinfecting the tonometer between patients and the skin contact area.
Choosing the most appropriate and safest tonometer during this pandemic by best-provided evidence relays on several aspects, including damage of nondisposable tips by repeated disinfectant use and corneal harm, the accuracy of measurement and a cost-effective comparison of disposable tips/caps.

**Goldmann Applanation Tonometry**

Although Goldmann applanation tonometry remains the gold-standard method for measuring IOP, the standard Goldmann applanation prism requires disinfection before reuse. Preventative measures include checking the tonometer for damage or breakage as cracks may harbor microorganisms, replacing the tonometer tip at least every 2 years, and adequate disinfection.[30]

Regarding disinfection, currently available evidence suggests that sodium hypochlorite (1:10 dilute bleach) is the only high-level disinfectant with broad efficacy against common infectious agents encountered in eye care, including adenovirus and herpes simplex virus. Similarly, both tonometer manufacturers[31] and the Centers for Disease Control and Prevention (CDC)[32] recommended only 1:10 dilute bleach for disinfecting application tonometers. Conversely, the use of 70% isopropyl alcohol (e.g., alcohol wipes) and 3% hydrogen peroxide was not sufficient to eliminate adenovirus and has been associated with adenovirus outbreak and accordingly is not considered by the CDC as high-level disinfectants.[32]

The Asia-Pacific Journal of Ophthalmology has recently published an article by Lam et al., and they recommend disinfecting patients’ contact areas on noncontact tonometers such as mandible bracket and frontal bracket with 70%–75% ethanol or isopropyl alcohol immediately after each use. While tonometers with direct contact with patient’s ocular surface such as Goldmann applanation tonometer (GAT) prisms were disinfected by immersion in either 1:10 diluted bleach solution with sodium hypochlorite or 3% hydrogen peroxide for at least 5 min, they favor rebound tonometer use instead of noncontact air puff tonometer and they claim that by following these guidelines in their ophthalmic practice in Hong Kong and China during the peak of COVID-19 pandemic, they were able to successfully achieve zero infection.[33]

Whilst sodium hypochlorite is likely to provide adequate disinfection against SARS-CoV-2, a safer practice to mitigate infection risk is to employ the use of disposable tonometer tips, such as the Tonosafe (Haag Streit Diagnostics, Bern, Switzerland) for applanation tonometry.[40] This seems to be the current practice among ophthalmologists.[33]

Regarding the measurement of IOP, the level of agreement with the conventional Goldmann prim seems to be reasonable, although data for eyes with IOP above 30 mmHg seems to be limited.[36,37] Furthermore, other studies supported that Tonosafe® prism is highly correlated to nondisposable GAT with comparable retest repeatability, suggesting that Tonosafe is an acceptable substitute for GAT.[38,39] The disposable tip may underestimate IOP slightly (compared with conventional Goldmann) for IOPs above 21 mmHg.[36]

At the cost of approximately $1.20 USD, Tonosafe is a cost-effective alternative even after accounting for maintenance and indirect costs. A United States study reported an increased cost of nondisposable prisms with an estimation of $36 400 plus for nondisposable GAT compared to $20 230 for Tonosafe per year. The increased cost of nondisposable prisms was derived from the added cost of cleaning solutions and labor involved for disinfection.[39] In contrast to most departments, the cleaning solution is routinely provided for disinfecting contact lenses and, as such, does not represent any additional cost.

**Air-Puff and Contact Pneumotonometry**

Non-contact air-puff tonometry is a popular method of use for IOP screening in optometric practices. Theoretically, instruments with high-speed air such as air puff tonometer can cause aerosolization. Therefore, they can pose risks to the health care provider and patients due to the generation of aerosol from the ocular surface. Britt et al. studied the disruption of the tear film, using a camera and flash that were electrically coupled to an NCT machine when a pulse of pressurized air was blown toward the eyes. They reported tear film dehiscence and micro aerosol formation.[40] In another study, Li et al. reported that aerosol could be produced by noncontact “air-puff” tonometer spraying. Aerosol fluctuates and increases with spraying times, showing a cumulative effect, and more aerosol can be produced without masks. If SARS-CoV-2 adheres to aerosol, it can form virus aerosol, which is likely to lead to its spread and transmission.[41]

Pneumotonometry is a contact method, which, although it provides reusable tips for use,[42] involves applanating the ocular surface and also utilizes compressed air, which could become aerosolized and also should be avoided.

It is rational to suspend the use of noncontact air-puff tonometry and contact pneumotonometry during this pandemic and rely on other methods of IOP measurement, as discussed below.

**Rebound and Contact Applanation Tonopentonometry**

Although both icare rebound tonometry (ice200, ic100, Icare Finland, Vantaa, Finland) and TonopenAVIA (Reichert,
Reichert Technologies, Buffalo, NY) tonometry involve contact with the eye, both provide disposable tips for use [Figure 1]. In addition, the typical working distance employed is more than that needed for GAT, thus maintaining a greater distance from the patient. Icare avoids the use of anesthetic drops and, therefore, potentially employs less measurement time than Tonopen.

There is reasonable inter-device agreement and consistency between icare and Tonopen with Goldmann applanation.\(^4^3\) However, these modalities may be less reliable at extreme IOP values (<10 mmHg and >24 mm Hg). Tonopen XL, may display the lower agreement with the other tonometers.\(^4^4\) Both icare and Tonopen tend to overestimate the GAT IOP values in eyes with thicker corneas (CCT values more than 555 µm).\(^4^5\) We would, therefore, recommend repeating measurements twice, especially where high values are suspected.

The estimation of the cost of handheld Tonopen XL cover is $0.42 per one tip cover and around $39,9370 per year after accounting for all associated costs.\(^3^9\) I-care tips are more expensive: The cost for 100 disposable for each icare system (excluding VAT) are; £70 (~$90) for Icare TA01i and ic100, and £50 ($65) for Icare PRO.\(^4^6\)

**Societal guidelines on the use of tonometry**

In a recent Eurotimes article, it was stated: “For IOP detection, we are using single-use, disposable, sterile tonometer for applanation tonometry. We avoid pneumo-tonometry (air puff, including ORA), which might be an aerosol-generating procedure (AGP), whereas we think rebound tonometry is acceptable as it probably is not an AGP.”\(^4^7\) Summarized below is available guidance from various organizations on the use of tonometry.

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**American Academy of Ophthalmology**

The American Academy of ophthalmology supports the use of diluted bleach for the disinfection of reusable tonometer tips for SARS-CoV-2 and adenovirus. If a tonometer tip is cleaned with alcohol and allowed to dry in room air, 70% alcohol solutions should be effective at disinfecting tonometer tips from SARS-CoV-2. However, alcohol will not effectively sterilize the tip against adenoviruses. That is because the virus causing COVID-19 is an enveloped virus, unlike the nonenveloped adenoviruses, that are much more resistant to alcohol. Ultimately, It is preferred to use single-use, disposable tonometer tips if available.\(^2^4,4^8\)

**Royal College of Ophthalmologists, UK**

The royal college of ophthalmologists advised not to use air-puff tonometry and use iCare tonometry or similar rebound tonometers. Goldmann slit lamp tonometry should be limited to those in whom its critical for care.\(^4^9\)

**The College of Optometrists, UK**

The college of optometrists’ guidance implies that IOP checks should be avoided in the primary care setting for individuals known to have healthy optic discs and visual field.\(^5^0\)

**The Royal Australian and New Zealand College of Ophthalmologists**

In their guidance, Royal Australian and New Zealand College of Ophthalmologists state: “Use iCare tonometry while standing beside the patient. Do not use puff tonometry and only use GAT if essential. When using GAT, disposable tips are preferred. If this is not available, 70% alcohol solutions should be effective at disinfecting tonometer tips from SARS-CoV-2. “Tonometer or any other equipment that has come into close contact with the patient or mucosal surfaces should be cleaned with alcohol wipes or chlorine dioxide disinfectant immediately after seeing a suspect or confirmed case.”\(^5^1\)

**Conclusion/Summary**

The recommendations from this article are summarized in Table 1.

In summary, currently, there is no established evidence of COVID-19 transmission through tonometry. Transmission of infection by this route, to date, seems unlikely, though theoretically possible in light of SARS-CoV-2 receptor ACE2 expression in cornea and conjunctiva. Eye care practitioners are urged to err on the side of caution and take measures to eliminate this risk. This article provides recommendations based on current theory and guidelines for the practice of safe tonometry during the COVID-19 era.
Table 1: Summary of tonometry types and recommendations

| Tonometry type           | Recommendation | Notes                                                                 | Cost/tip  | Cost/year* |
|--------------------------|----------------|------------------------------------------------------------------------|-----------|------------|
| GAT                      | Use with caution when essential (disposable prims and slit lamp guards in place) | Although hypochlorite likely to be an effective solution for disinfection of standard prims, safer practice is to use disposable prims | $100      | $36,400**  |
| Tonosafe®                | Recommended    | close working distance                                                | $1.19     | $20,230    |
| Air-puff tonometry       | Not recommended | Aerosolization of air particles possible                               | NA*       | NA*        |
| Pneumotonometry          | Not recommended | Aerosolization of air particles possible                               | NA*       | NA*        |
| Rebound i-care tonometry | Recommended    | Disposable tip                                                         | £0.70 (~$0.90) for i-care TA01i and ic100 | $46,000    |
| Tonopen applanation      | Recommended    | Further working distance than GAT                                       | $0.42     | $39,370    |
| tonometry                |                | Performed 2 readings to ensure consistency                              |           |            |

*Estimated cost based on equipment cost; **Costs including disinfection, NA as not recommended for use during COVID-19 era. NA: Not applicable, COVID: Coronavirus disease, GAT: Goldmann applanation tonometry.

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Conflicts of interest

There are no conflicts of interest.

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