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Drop instillation and glaucoma

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Abstract

Purpose of review—To describe the current state of knowledge regarding glaucoma patients' eye drop technique, interventions attempting to improve eye drop technique, and methods for assessing eye drop technique.

Recent findings—In observational studies, between 18.2 and 80% of patients contaminate their eye drop bottle by touching their eye or face, 11.3–60.6% do not instill exactly one drop, and 6.8–37.3% miss the eye with the drop. Factors significantly associated with poorer technique include older age, lack of instruction on eye drop technique, female sex, arthritis, more severe visual field defect, lack of positive reinforcement to take eye drops, lower educational level, low self-efficacy, and being seen at a clinic rather than a private practice. Among intervention studies, four of five studies using a mechanical device and three of four studies using educational interventions to improve technique showed positive results, but none of the studies were randomized controlled trials.

Summary—Poor eye drop technique is a significant impediment to achieving good control of intraocular pressure in glaucoma. Both mechanical device interventions and educational interventions offer promise to improve patients' technique, but studies with stronger designs need to be done followed by introduction into clinical practice.

Keywords

educational intervention; mechanical device intervention; medication use; technique

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Conflicts of interest

There are no conflicts of interest.

INTRODUCTION

Glaucoma affects over two million Americans, and about one-sixth of cases eventually result in blindness [1,2]. Eye drops aim to decrease intraocular pressure and are the first-line treatment for patients with glaucoma [3]. Proper eye drop technique involves multiple steps to instill the medication into the eye for maximum effectiveness without contaminating the bottle. However, in today's rushed and overburdened clinical settings, many patients are prescribed eye drops with little or no instruction on how to self-administer drops [4,5]. When patients do not instill eye drops correctly, their clinical outcomes can be negatively affected [5]. Glaucoma that is not effectively treated with eye drops can lead to blindness or the need for eye surgery. Therefore, interventions to educate patients on improving their eye drop technique are needed.

Correct eye drop technique requires a number of steps that are essential to get the medication into the conjunctival sac where it can confer the greatest benefit, while avoiding contamination of the bottle that can result in unwanted side-effects [6]. In general, national guidelines suggest following nine steps (Table 1) [7,8].

OBSERVATIONAL STUDIES

Although receiving instruction on eye drop instillation has been associated with better technique [9], patients report receiving little such education from their providers [5,10]. Just 18.5% of patients in a study by Gupta *et al.* [5] in India reported receiving instruction from their physician on correct technique. Similarly, in a study of 738 patients by Cohen Castel *et al.* [10] in Israel, only 16% of patients reported being explained eye drop technique by their family physician. In a large US-based observational study where the medical visit was videotaped, analysis of the videotapes revealed that only 40 of 255 patients (16%) received instruction about eye drop administration [11■]. Patients who did not have questions about eye drop administration had 4.8 times the odds of instilling exactly one drop as those who had at least one question [11■].

Using the *PubMed* search terms 'eye drop AND technique AND glaucoma', 15 observational studies were found that collected data on eye drop technique (Table 2) [12–15,9,11■,16–25,5,26]. Most studies were in agreement that not getting the medication into the eye, touching the tip of the bottle to the eye or face, and wasting drops were a problem for a significant number of patients. Five studies found that more than half the patients touched the bottle tip to the eye or contaminated the bottle [5,11■,22,23,27].

Most studies assessed the eye drop technique steps of instilling exactly one drop, getting the drop accurately into the eye, and/or avoiding contamination of the bottle; three studies assessed all of these steps [5,11■,26], whereas most others assessed just one or two of the steps (Table 2). One study additionally assessed hand washing, closing the eye after instillation, and punctal occlusion [25]. Contaminating the bottle by touching the eye or face was the most frequently missed step. Reported rates of contaminating the bottle in eight different studies ranged from 18.2 [26] to 80% (Table 3) [22,26,17,19,13,23,11■, 5,15,9,25,20,14,20]. Two other studies reported separate estimates for touching multiple

sites with the bottle; Sleath *et al.* [15] found that 34% of patients touched the eye or eyelash and 52% touched the face, whereas Tatham *et al.* [9] found that 15.3% touched the eye and 27.1% touched the eyelid or lashes. The three studies with the lowest rates of contaminating the bottle used a self-reported measure of technique [17,18] or used patients already enrolled in a randomized controlled trial [26]; therefore, it is likely that the higher estimates are more accurate for typical patients.

Instilling exactly one drop was another frequently missed step. The number of patients missing this step in seven different studies ranged from 11.3 [26] to 60.6% [23]. Missing the eye occurred less frequently, but was still a significant problem, with 6.8 [18] to 37.3% of patients experiencing this problem [20]. Missing the eye had consequences in the sense that it was correlated with more bottles used, which could cause patients to experience more cost-related barriers to adherence [20]. In addition to contaminating the bottle, instilling a single drop, and missing the eye, the study by Ikeda *et al.* [25] also measured several other steps with direct observation and found that only 41% washed their hands before instillation, 60% did not close their eyes after instillation, and 70% did not compress the nasolacrimal region after instillation.

Four studies found that older age was associated with poorer technique [9,12,13,18]. Other factors significantly associated with poorer technique included not having received instruction on eye drop technique [9], female sex [11■], arthritis [11■], more severe visual field defect [11■], lack of positive reinforcement to take eye drops [16], lower educational level [11■,18], low self-efficacy [15,16], and being seen at a clinic rather than a private practice [22]. No effect of race has been observed in relation to technique in most studies, although Sayner *et al.* [11■] found that African Americans were less likely to touch their face with the bottle tip during instillation.

METHODS OF ASSESSING EYE DROP TECHNIQUE

This section will discuss the ways that eye drop technique has been measured and the benefits and drawbacks of each method. Of the 24 technique studies reviewed – 15 observational studies from Table 2 and nine interventional studies from Table 4 – eight studies measured technique by video recording the patient's technique [9,11■,27, 12–16,28■■,29,30■,31–34,29,6,27], eight studies asked patients to self-report their technique (including one qualitative focus group study) [17–21,24,35,32], six studies involved direct observation by a study team member [5,22,23,25,26,33], and two studies did not state the technique assessment method clearly [6,31].

Results of studies using self-report and objectively assessed eye drop technique have both found high rates of incorrect use (Tables 2 and 4). Patients seem fairly willing to admit that they incorrectly perform eye drop instillation [17,18,20,34]. However, self-report may still be less reliable than more objective measures. More objective measures of eye drop technique include direct observation and video recording. In direct observation, an observer watches the patient attempt to instill eye drops and completes a checklist of which steps on a list are correctly performed. Video recording of patients' eye drop technique can be even better as it can allow multiple raters to watch the video, and then interrater reliability can be

calculated. Even if multiple raters cannot be used, a masked observer can grade the patient's performance, minimizing bias that might be introduced by an unmasked researcher.

INTERVENTIONAL STUDIES

Only nine studies included an intervention together with a control group or control phase that provided a basis for comparison of technique (Table 4). Seven of these studies (78%) showed a significant benefit of the intervention on at least one main outcome measure, such as technique, specific steps in technique, or ease of use [6,27,34,31,33,28■■,29]. Four of the seven used a mechanical dosing aid or modification to the bottle to make eye drop instillation easier [34,31,33,29]. In a crossover study, Nordmann *et al.* [34] found that the Xal-Ease delivery device (no longer available) reduced the number of patients who needed help instilling their drops, the number who touched their eye with the bottle tip, and the number who often or always missed their eye with the drop [35]. The Xal-Ease device was mounted on the face and held the bottle in a position that ensured accurate aim of the drop toward the eye. It also contained a button that the patient could press to release exactly one drop. Strungaru *etal.* [29] found that a mirror-hat delivery device, where a magnifying glass was attached to the brim of a standard baseball cap, reduced the number of patients touching the eye with the bottle from 37 to 13%, although no improvement was observed in instilling exactly one drop or getting the drop in the eye. Stack and McKellar [31] found that compared to a standard bottle, 87.5% of patients rated a black-tipped bottle (where the tip was painted black) as easier to use, and 67.5% used extra drops less frequently when using the black-tipped bottle. To our knowledge, no manufacturers are producing black-tipped bottles. Dietlein *et al.* [33] found that patients age 80 or older were better able to open the container with no help or explanation when a single-dose bottle was used, compared to a standard bottle. The patients were also more likely to correctly get a drop into the corneo-conjunctival area when they used a single-dose bottle [33]. Single-dose bottles are currently available for several, but not all, classes of glaucoma drops and are more expensive than standard containers.

Three studies successfully used educational interventions to improve eye drop technique [6,27,28■■]. Feng *et al.* [28■■] performed a prepost study of an educational video and handout, and found that the average technique score improved from 2.53 preintervention on a 15-point scale to 6.15 postintervention (P=0.008). Out of 15 items assessed, four showed statistically significant improvements: holding open the eyelid, squeezing one drop into the pocket (conjunctival sac), closing the eye for 1 min, and punctal occlusion [28■■]. In a prepost study of an eye drop chart explaining proper technique, McVeigh and Vakros [6] found that hand hygiene, shaking the bottle before use, and tear duct occlusion occurred more frequently in the postintervention phase; nine other steps showed no significant improvement. In the third study, Lazcano-Gomez *et al.* [27] measured eye drop instillation technique before and after the ophthalmologist provided instruction on technique. The patient's initial technique was videotaped and the patient then watched the video with the ophthalmologist, who pointed out the patient's mistakes and explained how to instill the eye drops correctly. After patients received education, the mean number of drops squeezed out of the bottle decreased from 1.5 to 1.2 (P=0.011) and the percentage of patients who touched the eye or face declined from 64.4 to 28.9% (P=0.05) [27].

There were two exceptions to these generally successful results. Salyani and Birt [32] found that the mean rating of ease of use of eye drops was actually worse after patients started using an eye drop guide similar to Xal-Ease – a device designed to direct the bottle accurately toward the eye – than before. Al-Busaidi *et al.* [30■] found that both a group who attended glaucoma educational sessions and a group who did not attend had poor technique more than 1 year later. Sixteen percentage of people who attended the sessions had good technique, compared to 23% of those who did not attend (P=0.498). The majority of patients had attended the sessions at least 3 years before the study was done, which may have been too long to retain any benefit from attending. Patients may have also received eye drop technique education from sources other than the hospital's educational programme, such as their pharmacists.

As there have been only three intervention studies that used an educational intervention to improve technique, none of which were randomized or had control groups [6,27,28■■], more studies of practical educational interventions are needed. The other studies used a mechanical delivery aid or modification to the bottle, which was helpful, but they have not been widely adopted [34,31,33]. Even if mechanical delivery aids are used, patients still need to know how to get a single drop into the eye accurately without contaminating the bottle, so there still is a need for effective educational interventions. Although the printed material intervention by McVeigh and Vakros [6] showed some success, only three of 12 steps showed significant improvement after the intervention, the design lacked a control group, and a self-report measure of technique was used. Lazcano-Gomez *et al.* [27] used objective video recording of technique, but the intervention required significant provider effort, and this study also lacked a control group. Feng *et al.* [28■■] also showed improvement and used an objective technique measure, but their study was small and lacked a control group.

CONCLUSION

The literature shows that many glaucoma patients have difficulty with at least one key step in eye drop instillation technique, such as avoiding contamination of the bottle, instilling exactly one drop, or getting the drop accurately into the eye. Older patients, patients with more severe visual field defect, less educated patients, and patients with comorbidities such as arthritis may be particularly at risk for poor technique. Both mechanical device interventions and educational interventions appear to provide benefit toward improving patients' technique but have not been adopted or are not available. As providers often do not have time to educate their patients about technique during the medical visit, interventions that can be delivered outside the clinic visit may be particularly helpful.

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KEY POINTS

- Patients commonly perform important steps in glaucoma eye drop instillation incorrectly.
- Large numbers of patients squeeze out multiple drops or contaminate the eye drop bottle when instilling drops.
- In studies, eye drop technique should be assessed by objective methods, ideally by video recording.
- Helpful interventions to improve eye drop technique include mechanical devices and educational printed or video materials.

Table 1.

Steps of proper eye drop technique

1. Wash hands to keep the bottle clean when touching it
2. Mix the medication by turning the bottle over several times. Shaking the bottle introduces unwanted air bubbles, but turning the bottle over mixes the medication without creating air bubbles
3. Squeeze the bottle firmly for just long enough to squeeze out one drop, not several drops or a stream of drops. The eye can only hold one drop, so squeezing out multiple drops, even if they are aimed accurately, tends to cause liquid to spill out of the eye and down the face
4. Hold open the lower eyelid with a finger of the nondominant hand to expose the conjunctival sac
5. Get the drop accurately into the eye or inferior fornix
6. Avoid touching the eye or face with the bottle tip at any time because of risk of contaminating the bottle with facial microbes
7. Close the eye after instillation for at least 1 min without squeezing it shut
8. Alternatively, perform punctal occlusion by placing a finger over the tear duct and exerting gentle pressure to prevent the medication from traveling through the tear duct into the nose
9. Remove excess fluid from the face with a tissue to avoid localized side-effects on the skin

Table 2.

Observational studies assessing eye drop instillation technique

Author, year	Design	Outcome measure	Results
Hennessy *et al.*[12]; Hennessy*et al.* [13]	Cross-sectional observational,*n* = 204	Successful instillation of a drop onto the ocularsurface from videorecording of technique	71% able to get any drops onto the ocular surface; 52%able to get exactly one drop onto the ocular surface; 39%able to get exactly one drop onto the ocular surface w/otouching ocular surface; 33% touched the eye with bottletip
Sleath *et al.* [14]; Sleath *et al.* [15]	Longitudinal observational,*n* = 102	Video recording oftechnique	38% had perfect technique; 80% got a drop in the eye onthe first attempt; 70% instilled only one drop; 34%touched eye or eyelash with bottle tip; 52% touched face
Tatham *et al.* [9]	Cross-sectional observational, *n* = 85	Video recording oftechnique	54.1% had poor technique; 11.8% missed eye, 15.3%touched tip of bottle to eye, 27.1% touched tip of bottleto eyelid or lashes
Sayner *et al.* [11■]; Carpenter *et al.*[16]	Longitudinal observational,*n* = 279	Video recording oftechnique	51% instilled exactly one drop; 90% got the drop in the eyeon the first attempt; 60% touched the eye or face with thebottle tip; provider education about adherence andprovider inclusion of patient input into treatment planpredicted decrease in IOP; relationships not mediated byadherence or eye drop technique
Tsai *et al.* [17]	Single-groupobservational survey,*n* = 253	Self-reported method of administering eye drops	82.6% self-administered drops; 36.4% administered dropsstanding, 37.8% sitting, 31.6% lying down; 16.3% usedmirror; 36.4% always washed hands beforeadministration; 25.4% always, usually, or sometimestouched their eye w/tip of bottle
Kholdebarin *et al.*[18]	Observational survey,*n* = 500	Self-reported	6.8% missed eye, 28.8% contaminated bottle wheninstilling drops
Curtis *et al.* [19]	Cross-sectional survey, *n* = 100	Self-reported (responses toquestionnaire)	23% did not know the names of their eye drops; 13% saidthey had problems instilling the drops; 49% correctlyclosed their eyes after instillation; 41% had poorunderstanding of glaucoma, 49% had partialunderstanding, 10% had good understanding
Kawai-Tsuboi *et al.* [20]	Single-group cohort,*n* = 67	Self-reported (5-itemquestionnaire of technique and adherence)	76.1% instilled exactly one drop; 62.7% instilled itaccurately
Taylor *et al.* [21]	Focus groups, *n* = 21	NA	Most patients had misconceptions about technique, althoughthey thought they knew the correct technique
Brown *et al.* [22]	Observational cros-ssectional, *n* = 150	Direct observation by examiner	13% failed to instill drops in both eyes after one or moreattempts; 80% contaminated the bottle; 82% claimed tohave no difficulty using the medications properly; 21%unnecessarily tried to instill more than one drop in one or both eyes
Hosoda *et al.* [23]	Single-groupobservational, *n* = 142	Direct observation by examiner	39.4% instilled one drop; 54.9% touched eye with tip ofbottle
Konstas *et al.* [24]	Observational survey,*n* = 100	Direct observation by examiner	53% very capable of instilling medication correctly
Ikeda *et al.* [25]	Single-groupobservational, *n* = 27	Direct observation by examiner	20% performed entire technique correctly; 60% did notclose eyes, 70% did not compress the nasolacrimalregion after application; 63% reported they sometimesforgot to apply eye drops; 41% washed hands beforeusing eye drops; 85% applied exactly one drop

Author, year	Design	Outcome measure	Results
Gupta *et al.* [5]	Single-group cohort, $n = 70$	Direct observation by examiner	Used 1.8 drops per instillation; 50% squeezed out exactlyone drop; 68.6% did not misdirect the drop; 75.7%touched the eye with the bottle tip; 8.5% performed allsteps correctly
Schwartz *et al.* [26]	Secondary analysis of RCT data, $n = 163$	Direct observation by examiner	88.6% reported having no difficulty administering eyedrops; 18.2% touched eye or adnexa with bottle; 10.3%missed eye; 11.3% administered more than one drop

IOP, intraocular pressure; NA, not applicable; RCT, randomized controlled trial.

Table 3.

Frequency of missing each eye drop technique step in observational studies

Step (number of studies)	Range of estimates of patients performing step incorrectly	Estimates
Contaminating the bottle (n = 10)	18.2–80%	18.2% [26], 25.4% [17], 28.8% [19], 33% [13], 54.9% [23], 60%[11■], 75.7% [5], 80% [22], 34% (eye or eyelash) and 52%(face) [15], 15.3% (eye) and 27.1% (eyelid or lashes) [9]
Instilling exactly one drop (n = 7)	11.3–60.6%	11.3% [26], 15% [25], 23.9% [20], 30% [14], 49% [11■], 50%[5], 60.6% [23]
Drop misses the eye (n = 8)	6.8–37.3%	6.8% [19], 10% [11■], 10.3% [26], 11.8% [9], 20% [14], 29%[13], 31.4% [5], 37.3% [20]
Washing hands before instillation (n = 1)	59%	59% [25]
Closing eyes after instillation (n = 1)	60%	60% [25]
Compressing the nasolacrimal region after instillation (n = 1)	70%	70% [25]

Table 4.

Intervention studies assessing eye drop instillation technique

Author, year	Design	Intervention	Outcome measure	Results in intervention group or phase	Results in control group or nonintervention phase
Stack and McKellar [31]	Prepost intervention, $n = 40$	Black-colored bottle tips	Ease of use, technique	87.5% said black-tipped bottles were easier to use; 67.5% said they instilled extra drops less frequently with black-tipped bottles	NA
Salyani and Birt [32]	Prepost intervention, $n = 93$	Eye drop guide	Scale of ease of use of the guide	Mean rating of ease of use with guide:6.0 of 10	Mean rating of ease of use without guide: 8.0 of 10 ($P<0.01$)
Dietlein *et al.* [33]	Observational Cross-sectional, $n = 44$	New single-dose bottle	Direct observation by examiner	Patients age above 80 with new single-dose bottle: 34% opened container w/o help or explanation; 43% placed no drop on corneo-conjunctival area	Patients age 50–65: 73% opened container w/o help or explanation ($P=0.002$); 5% placed no drop on corneo-conjunctival area ($P=0.001$); patients age above 80 using standard bottle: 64% opened container w/o help or explanation ($P=0.009$); 11% placed no drop on corneo-conjunctival area ($P = 0.003$)
Nordmann *et al.* [34]	Randomized crossover, $n = 211$	Xal-Ease delivery device	Self-reported technique	6.9% would need someone to help with instillation ($P<0.001$); 3.2% touched eye with bottle tip ($P<0.001$); 62.4% rarely or never missed eye with drop ($P=0.03$)	18.1% would need someone to help with instillation; 35.6% touched eye with bottle tip; 49.9% rarely or never missed eye with drop
Strungaru *et al.* [29]	Prepost intervention, $n = 30$	Mirror-hat delivery aid	Video recording of technique	After implementing a mirror-hat drop delivery aid, 13% contaminated the bottle ($P=0.02$); 86.7% could see the drop with the device ($P=0.0005$)	37% contaminated the bottle before intervention; 40% could see the drop without the device
McVeigh and Vakros [6]	Prepost intervention, $n = 25$	Printed eye drop chart tool	Correct instillation (assessment method unclear)	Hand hygiene: 92% ($P=0.029$); shaking bottle before use: 84% ($P=0.001$); tear ducts occlusion: 72% ($P=0.015$)	Hand hygiene: 64%; shaking bottle before use: 40%; tear ducts occlusion: 44%
Lazcano-Gomez *et al.* [27]	Prepost intervention, $n = 45$	Ophthalmol-ogist education	Video recording of technique	Patients squeezed out mean of 1.2 drops ($P = 0.01$ 1); 28.9% touched the eye or face with the bottle tip ($P=0.05$)	Patients squeezed out mean of 1.5 drops; 64.4% touched eye or face with bottle tip
Al-Busaidi *et al.* [30■]	Observational cross-sectional, $n = 55$	Small-group glaucoma educational sessions	Video recording of technique	16% of patients who attended a small-group educational session had good technique ($P=0.498$)	23% of patients who never attended an educational session had good technique
Feng *et al.* [28■■]	Prepost intervention, $n = 34$	Educational video and handout	Video recording of technique	Average eye drop technique score postintervention: 6.15 of 15 points ($P=0.008$)	Average eye drop technique score preintervention: 2.53 points

NA, not applicable; NS, not significant. All *P* values represent between-group comparisons (intervention versus control).