Short term comparative study of topical 2% carteolol with and without benzalkonium chloride in healthy volunteers

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Abstract

Aim—A crossover, randomised double blind study was undertaken in 30 healthy volunteers, in order to compare the tolerance of 2% carteolol with and without preservative in short term use.

Methods—Complete ophthalmic examinations were performed before and after instillation of one drop of the solution, and after 3 days of preservative treatment. After a 5 day washout, the same examinations were done with the second drug.

Results—Results showed good general tolerance for both formulations. No significant difference in subjective tolerance, corneal aesthesiometry, punctuate keratitis, Schirmer's test, intraocular pressure (IOP) decrease (about 25% in the two groups at 3 hours, 10% after 3 days of treatment), resting cardiac frequency, or blood pressure was observed. However, break up time was significantly reduced from baseline by preserved carteolol both at 3 hours (10.40 (5.9) seconds to 6.15 (3.9) seconds, \( p<0.001 \)) and after 3 days (7.72 (5.5) seconds, \( p=0.04 \)). Preservative free carteolol did not significantly change the break up time (baseline 9.08 (5.7) seconds; 3 hours = 7.88 (5.5) seconds, not significant; day 3 = 8.35 (5.8), non-significant).

Conclusions—These results confirm that carteolol is well tolerated, either with or without preservative. The preservative free group showed better stability of the tear film, without loss of effect on IOP. This difference, although mild in the healthy young subjects in the present study could be much more relevant in those patients treated long term, older patients, and/or those suffering from ocular surface disorders. In such instances, preservative free drugs could be of potential benefit to protect the lacrimal fluid integrity and corne conjunctival surface.

Patients and methods

PATIENT SELECTION

This study was performed in healthy volunteers, in the Centre of Clinical Pharmacology of the University of Nice, France, after receiving the authorisation of the ethics committee (CCPRB) of Marseilles, France. Selection criteria were: informed consent, age ranging from 18 to 40 years, normal ophthalmic examination, including best corrected visual acuity above 20/25, no subjective sensation such as itching, foreign body sensation or burning, normal slit lamp examination, break up time above or equal to 5 seconds, negative fluorescein staining, Schirmer's test superior or equal to 6 mm at 5 minutes, and IOP between 8 and 18 mm Hg. Subjects with history of ocular disease, cardiac or respiratory contraindication to \( \beta \) blockers, topical or systemic medicines for less than 7 days before the experiment, except oral contraception, myopia more than 4 dioptres, history of ocular allergy, contact lens wearing, monophthalmos, or risk of pregnancy were not selected. Moreover, electrocardiogram, resting heart rate, and systemic pressure were recorded in the last 2 weeks before study. Subjects with any abnormality were not selected. At the end of the
selection period, 30 healthy volunteers con-
formed to all these criteria and took part in the
study.

STUDY DESIGN
Solutions of 2% carteolol were prepared with
and without benzalkonium chloride (0.005%,
as in the commercial solution: Carteol, man-
ufactured by Chauvin, Montpellier, France), in
identical vials numbered in a randomised man-
ner. One bottle was used for each instillation,
so that six vials were used for each study
period. Only one eye was tested and received
the two formulations successively. Fifteen sub-
jects received drugs into their right eye and the
other 15 into the left eye. Drug and eye assign-
ments were done with the help of a randomised
computerised method. During the first study
period, ophthalmic examinations were per-
formed immediately before and 30, 60, and
180 minutes after the instillation of one drop
of the tested solution. Subjects then instilled one
drop twice a day for 2 days and one drop in the
morning of the third day. New ophthalmic and
general examinations were done 8 hours after
the last instillation. After a 5 day washout
period, the same experiment was done in the
same eye, with the other solution.

CLINICAL EXAMINATIONS
Before the first instillation of carteolol solu-
tion, systemic pressure, heart rate, distant
visual acuity, aesthesiometry, pupillary diam-
eter, slit lamp scoring of conjunctival hypera-
emia, oedema and epiphora, break up time,
given by the mean of two successive measure-
ments, fluorescein test, graded 0 to 4 according
to the extent of staining, Schirmer’s test at 5
minutes and applanation tonometry were
recorded. In order to avoid a possible interac-
tion with the preservative included in the
anaesthetic used for applanation tonometry, we
used a non-preserved anaesthetic (0.4% oxy-
buprocaine, Cebesine, Chauvin). The carteolol
solution was administered 30 minutes after
applanation tonometry to avoid any interfer-
ce of the anaesthetic in evaluation of
tolerance. After the first instillation, immediate
tolerance was therefore evaluated by the
subject on a visual analogue scale from 0 (not
irritating) to 100 (extremely irritating), and
subjective sensations of itching, burning, for-
eign body sensation, and photophobia were
recorded at 10 minutes by a scoring system of
intensity ranging from 0 to 3. If available, du-
ration of sensation was recorded. All oph-
thalmic examinations were repeated at 30, 60,
and 180 minutes, except pupil diameter and
Schirmer’s test. Systemic tension and heart
pulse rate were recorded at 60 and 180
minutes. Following repeated administration, all
examinations were performed 8 hours after
the last instillation in each period. The second
period was conducted under the same protocol
with the other solution tested.

STATISTICAL ANALYSES
Comparability of subjects assigned to treat-
ment sequence 1 (carteolol with benzalkonium
followed by unpreserved carteolol) and se-
quence 2 (unpreserved carteolol followed by
the preserved solution) was assessed for each
criterion using the Mann–Whitney non-
parametric test. No carryover effect was
detected and therefore data of both sequences
were pooled. Analysis of variance was per-
formed for each variable and time. In case of
significant difference, Mann–Whitney U test or
Wilcoxon test for paired variables were per-
formed. p Values under or equal to 0.05 were
considered significant.

Results
The 30 volunteers in this study were 18
females and 12 males, 19 to 40 years old. Their
mean age was 26.7 (SD 5.2) years. At the
beginning of the study, before the first instilla-
tion, the two groups were fully comparable, as
eyes receiving benzalkonium or not did not dif-
fer significantly in any ophthalmic or systemic
criterion tested. Very few side effects were
observed during the study. They were limited
to three mild superficial punctate keratitis (two
cases with benzalkonium and one case in the
preservative free group), that were resolved in a
few days without treatment, and did not call for
the experiment to be stopped.

SINGLE INSTILLATION
Subjective tolerance at instillation quantified
by a visual analogue scale from 0 to 100 mm
showed a very good tolerance in both groups—
3.66 (6.33) mm with carteolol with benzalko-
nium, v 2.83 (5.83) mm with preservative free
carteolol (p=0.27, non-significant). No signifi-
cant difference could be found between the
two groups in grading of subjective symptoms,
visual acuity, aesthesiometry, pupillary diam-
eter, conjunctival oedema, epiphora, and fluo-
rescein test scoring. None of these criteria
changed significantly from baseline in any
group.

Break up time, however, was significantly
reduced compared with baseline by preserved
carteolol at 3 hours (10.4 (5.9) seconds to 6.1
(3.9) seconds, p=0.001), whereas benzalko-
nium free carteolol did not change the break
up time significantly (baseline 9.1 (5.7) sec-
onds; 3 hours 7.9 (5.5) seconds, not signifi-
cant). At this time point, the decrease of break
up time from baseline was significantly higher
in the benzalkonium group (−4.4 (6.3) sec-
onds) than in the preservative free one (−1.1
(6.4) seconds, p=0.04).

IOP was similarly lowered in both groups,
about −3 mm Hg. This was approximately a
25% reduction, without any difference be-
tween the two treatments (Table 1). Blood
pressure showed a very slight decrease after
instillation of both formulations, less than 5
mm Hg for diastolic pressure and less than 10
mm Hg for systolic pressure, with no signifi-
cant difference between the two groups.

Resting pulse rate also decreased after instilla-
tion, with no significant difference between
the two treatments (Table 2).

REPEATED INSTILLATIONS
After 3 days of treatment (six instillations), no
difference could be found between the two
Table 1  Results of pupillary diameter, fluorescein test, break up time, and IOP after instillation of one drop of carteolol with and without preservative (comparison by analysis of variance (SD))

<table>
<thead>
<tr>
<th></th>
<th>Carteolol without benzalkonium</th>
<th>Carteolol with benzalkonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupil diameter (mm)</td>
<td></td>
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</tr>
<tr>
<td>Baseline</td>
<td>3.1 (0.8)</td>
<td>3.3 (0.7)</td>
</tr>
<tr>
<td>T0 + 30 minutes</td>
<td>3.1 (0.7)</td>
<td>3.3 (0.7)</td>
</tr>
<tr>
<td>T0 + 1 hour</td>
<td>3.3 (0.8)</td>
<td>3.1 (0.7)</td>
</tr>
<tr>
<td>T0 + 3 hours</td>
<td>3.2 (0.9)</td>
<td>3.5 (0.7)</td>
</tr>
<tr>
<td>Fluorescein test (cotation 0–4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T0 + 30 minutes</td>
<td>0.4 (0.8)</td>
<td>0.2 (0.4)</td>
</tr>
<tr>
<td>T0 + 1 hour</td>
<td>0.4 (0.8)</td>
<td>0.3 (0.5)</td>
</tr>
<tr>
<td>T0 + 3 hours</td>
<td>0.4 (0.7)</td>
<td>0.3 (0.7)</td>
</tr>
<tr>
<td>Break up time (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>9.0 (5.1)</td>
<td>10.4 (5.9)</td>
</tr>
<tr>
<td>T0 + 30 minutes</td>
<td>8.1 (5.4)</td>
<td>7.9 (5.7)</td>
</tr>
<tr>
<td>T0 + 1 hour</td>
<td>7.3 (5.9)</td>
<td>7.4 (6.4)</td>
</tr>
<tr>
<td>T0 + 3 hours*</td>
<td>7.9 (5.5)</td>
<td>6.1 (3.9)†</td>
</tr>
<tr>
<td>Intraocular pressure (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>13.8 (1.6)</td>
<td>13.7 (1.9)</td>
</tr>
<tr>
<td>T0 + 30 minutes</td>
<td>10.3 (1.7)</td>
<td>11.3 (1.6)</td>
</tr>
<tr>
<td>T0 + 1 hour</td>
<td>10.5 (1.9)</td>
<td>10.1 (1.4)</td>
</tr>
<tr>
<td>T0 + 3 hours</td>
<td>10.5 (1.9)</td>
<td>10.8 (1.9)</td>
</tr>
</tbody>
</table>

*Decrease in BUT at 3 hours from baseline was significantly lower in the benzalkonium free group than in the preserved carteolol (p=0.04).
†Significantly lowered compared with baseline (p<0.001).

Table 2  Heart rate (SD) after a single instillation (pulses/minute). Statistical analysis did not show any difference between the two treatments

<table>
<thead>
<tr>
<th></th>
<th>Carteolol without benzalkonium</th>
<th>Carteolol with benzalkonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>80.76 (9.70)</td>
<td>79.56 (9.81)</td>
</tr>
<tr>
<td>T0 + 1 hour</td>
<td>71.23 (8.58)</td>
<td>69.70 (8.74)</td>
</tr>
<tr>
<td>T0 + 3 hours</td>
<td>69.23 (9.64)</td>
<td>67.56 (8.81)</td>
</tr>
</tbody>
</table>

Table 3  Distant visual acuity, pupil diameter, asthesiometry, Schirmer’s test, break up time, fluorescein test, and IOP after 3 days of treatment (SD)

<table>
<thead>
<tr>
<th></th>
<th>Carteolol without benzalkonium</th>
<th>Carteolol with benzalkonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distant visual acuity (20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>24.2 (1.6)</td>
<td>23.8 (2.2)</td>
</tr>
<tr>
<td>3 days</td>
<td>24.8 (2.0)</td>
<td>24.2 (2.2)</td>
</tr>
<tr>
<td>Pupil diameter (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>3.1 (0.8)</td>
<td>3.3 (0.7)</td>
</tr>
<tr>
<td>3 days</td>
<td>3.4 (0.5)</td>
<td>3.38 (0.44)</td>
</tr>
<tr>
<td>Aesthesiometry (mg/surface)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>13.6 (2.3)</td>
<td>12.5 (1.9)</td>
</tr>
<tr>
<td>3 days</td>
<td>11.4 (0.6)</td>
<td>11.4 (0.9)</td>
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<tr>
<td>Schirmer’s test (mm at 5 minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>25.7 (11.7)</td>
<td>20.60 (12.68)</td>
</tr>
<tr>
<td>3 days</td>
<td>13.3 (10.4)</td>
<td>17.03 (13.91)</td>
</tr>
<tr>
<td>Break up time (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>9.1 (0.2)</td>
<td>10.4 (5.9)</td>
</tr>
<tr>
<td>3 days</td>
<td>8.4 (5.7)</td>
<td>7.7 (5.5)*</td>
</tr>
<tr>
<td>Fluorescein test (graded 0 to 4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 days</td>
<td>0.1 (0.3)</td>
<td>0.1 (0.4)</td>
</tr>
<tr>
<td>IOP (mm Hg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>13.8 (1.7)</td>
<td>13.7 (1.9)</td>
</tr>
<tr>
<td>3 days</td>
<td>12.4 (1.8)</td>
<td>12.4 (1.9)</td>
</tr>
</tbody>
</table>

*Significantly decreased from baseline (p=0.04).

Discussion

Almost all antiglaucoma drugs are currently available in association with benzalkonium chloride, a quaternary cationic surfactant, used at concentrations ranging from 0.005% to 0.01%. Its ocular toxicity was documented as early as 1941, and was found relevant at concentrations as low as 0.004%. Benzalkonium chloride through its surfactant effects alters tear fluid stability and reduces break up time. At a concentration of 0.005%, benzalkonium chloride causes epithelial cell wrinkling and peeling with exposure of underlying cells. At 0.01%, it may induce strong epithelial alterations, and at higher concentrations it causes strong damage to corneal stroma and endothelium.

Only a few studies have compared preservative free antiglaucoma drugs to preserved commercial preparations. In vitro, Williams et al investigated benzalkonium chloride, and three pure and preserved β blockers (timolol, betaxolol, and levobunolol), in tissue cultures of human Tenon’s capsule fibroblasts, and demonstrated irreversible toxicity of preservative and preserved drugs. Preservative free timolol showed significantly less toxicity than the commercial solution with 0.01% benzalkonium, and levobunolol was the least toxic, probably as a result of a lower concentration of benzalkonium chloride in this preparation (0.004% benzalkonium). In experimental models, Young et al showed, after glaucoma surgery, more myofibroblasts in the conjunctiva of rabbits treated for 4 months before surgery with pilocarpine, timolol, or artificial tears with benzalkonium chloride. An increase of fibrous tissue has also been observed in rabbits treated with preparations of metipranolol and pilocarpine, preserved with benzalkonium and cetirizonium chloride respectively, for 3 months, compared with non-preserved drugs.

In humans, a recent study of 20 patients by timolol with benzalkonium to timolol without preservative could significantly increase tear turnover values, although break up time remained significantly lower both in benzalkonium and benzalkonium free timolol compared with normal control subjects, without a significant difference in the two groups. This may indicate that glaucoma drugs may impair the tear film, but that use of benzalkonium chloride entails additional side effects. In other studies in glaucoma patients, removal of benzalkonium chloride from a timolol preparation restored the permeability and the metabolism of corneal epithelium and improved break up time.

However, these infrequent human studies were not prospective and randomised, nor did they compare in a homogeneous patient population preserved and preservative free preparations of antiglaucoma drugs. Our crossover randomised study was designed with healthy volunteers to look for differences of tolerance between two preparations of carteolol, with and without preservative, in short term use. We confirmed good tolerance for both preparations, which is consistent with the safety of this.
drug reported in clinical studies with preserved carteolol.15 16 19

We also found in this study that the IOP lowering effect of carteolol was not reduced by suppressing benzalkonium. We observed that the decrease in IOP (around 2.5 mm Hg at peak) was in accordance with previously published studies on carteolol.18–21 It has been suggested that benzalkonium chloride, through its toxic effects on ocular surface epithelia, enhances penetration of the active compound. Controversies thus remain concerning the effectiveness of unpreserved antiglaucoma drugs. Betaxolol without preservative appeared to be as efficient as the commercial solution in reducing IOP,20 and De Jong et al.16 confirmed that unpreserved timolol was both less toxic than, and as effective on IOP as, the preserved solution.

In the present work, we found a significantly decreased break up time after one drop of and after a 3 day treatment with preserved carteolol compared with the unpreserved preparation which did not modify tear fluid stability significantly. This is probably due to the surfactant property of benzalkonium chloride. However, these results in young healthy volunteers could be much more relevant in older glaucoma patients, who often suffer from various ocular surface disorders and quantitative or qualitative tear deficiency. Inflammatory changes can be found in the conjunctiva of a majority of multireacted glaucoma patients. Whether or not benzalkonium chloride is the main factor responsible for ocular surface toxicity remains to be determined. Only long term well controlled randomised prospective studies comparing preserved with unpreserved β blockers, in patients with and without ocular surface diseases, can address this issue. Our study is one of the first attempts, but these results need to be confirmed in large assays in glaucoma patients for a conclusive investigation of the consequences of long term use of preservatives on fragile ocular structures. Studies of preservative effects may stimulate interest in developing unpreserved solutions for patients with a high risk of toxicity or undergoing filtering surgery.

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