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Role of Antimuscarinics Combined with Alpha-Blockers in the Management of Urinary Storage Symptoms in Patients with Benign Prostatic Hyperplasia: An Updated Systematic Review and Meta-analysis

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1 **Adult Urology**

2

3 **Role of Antimuscarinics Combined with Alpha-blockers in the Management of Urinary**
4 **Storage Symptoms in Patients with Benign Prostatic Hyperplasia: An Updated**
5 **Systematic Review and Meta-analysis**

6

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ABSTRACT

Purpose: To evaluate the efficacy and safety of combining antimuscarinics with alpha-blockers to treat storage symptoms in men with benign prostatic hyperplasia.

Materials and Methods: Searches were carried out on PubMed, MEDLINE, EMBASE, and Cochrane databases to identify randomized, placebo-controlled trials published before February 15, 2022, assessing the efficacy or safety of antimuscarinics in men with benign prostatic hyperplasia treated with alpha-blockers. Further meta-analyses were performed using standardized mean difference (SMD) and risk ratio (RR).

Results: A total of 12 randomized trials were included in the systematic review. The meta-analysis showed no impact of antimuscarinics on the number of urgencies per day (SMD= -0.23 [95%CI: -0.64–0.17]; p=0.21). However, the use of antimuscarinics was associated with a small reduction of micturition episodes per day (SMD= -0.19 [95%CI: -0.37; -0.01]; p=0.045). With regards to side-effects, post-void residual increased slightly in patients treated with antimuscarinics (SMD=0.26 [95%CI: 0.15; 0.37]; p<0.01). In addition, there was a higher risk of acute urinary retention (RR=3.26 [95%CI: 1.35; 7.86]; p=0.02), dry mouth (RR=3.43 [95%CI: 1.86; 6.32]; p<0.001), and constipation (RR=2.92 [95%CI: 1.48; 5.73]; p<0.001) with the use of antimuscarinics. Finally, the risk of treatment interruption due to adverse events was higher for the patients treated with antimuscarinics (RR=1.74 [95%CI: 1.27; 2.38]; p<0.01).

Conclusion: The addition of antimuscarinics to alpha-blockers was not associated with a substantial reduction in urgencies and micturition episodes in BPH patients with storage symptoms. In addition, the toxicity profile was not in favor of antimuscarinic use in these patients.

1 INTRODUCTION

2 Benign prostatic hyperplasia (BPH) results from active proliferation of the transitional zone of
3 the prostate gland. While the prevalence of this condition among men over 65-years of age is
4 high,¹ the severity of related lower urinary tract symptoms and their impact on quality of life
5 (QoL) vary from one patient to another.² Bladder outlet obstruction (BOO) is frequently
6 associated with voiding symptoms, but storage symptoms including urgency and frequency are
7 also observed in patients with BPH.³

8 Although BOO has long been considered the predominant etiology for storage
9 symptoms in BPH patients, many recent data suggest that other bladder-related mechanisms
10 may also be involved.^{4, 5} For example, a large population-based survey showed that the
11 prevalence of storage symptoms increased with age without any difference between men and
12 women.² In addition, several urodynamic studies reported that detrusor over-activity was more
13 frequent in aging men, regardless of the presence of BOO.^{6, 7} As a consequence, storage
14 symptoms may be primarily age-related rather than prostate-centered.

15 Based on these data, the historically contra-intuitive use of antimuscarinics has been
16 proposed to treat storage symptoms in BPH patients. Given the risk of acute urinary retention
17 related to the inhibition of bladder contractions, it has been suggested that antimuscarinics
18 should only be used in patients with a post-void residual (PVR) of less than 200 ml.⁸ However,
19 there is contradictory evidence to support the efficacy and safety of antimuscarinics in BPH
20 patients. The last meta-analyses specifically assessing the efficacy of antimuscarinics on storage
21 symptoms in men with BPH were published in 2013⁹ and 2014,⁸ and several large, randomized,
22 controlled trials (RCTs) have been published since then.⁹⁻¹² The meta-analysis published in
23 2017 by Dahm et al. was not specifically dedicated to the evaluation of antimuscarinics in the
24 setting of BPH and the main endpoint was the evaluation of the global International Prostate
25 Symptoms Score (IPSS), which does not specifically assess storage symptoms.¹³

1 Against this backdrop, our aim was to provide an updated systematic review and meta-
2 analysis of available data from RCTs evaluating the role of antimuscarinics combined with
3 alpha-blockers to treat BPH patients with storage symptoms using more specific instruments.

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1 MATERIALS AND METHODS

2 Search strategy

3 A computerized, bibliographic search of PubMed, MEDLINE, EMBASE, and the Cochrane
4 database was conducted in February 2022 using a free text protocol applying only “Humans”
5 and “English” filters. Different combinations of the following keywords were used:
6 (Muscarinic Antagonists[MeSH] OR Tolterodine[All Fields] OR Fesoterodine[All Fields] OR
7 Propiverine[All Fields] OR Trospium[All Fields] OR Darifenacin[All Fields] OR
8 Solifenacin[All Fields] OR Oxybutynin[All Fields]) AND (Prostatic Hyperplasia[All Fields]
9 OR ‘Lower Urinary Tract symptoms’[All Fields]). Studies including the following keywords
10 were excluded from the search: (Review[Publication Type] OR Surgery[MeSH] OR
11 Compliance[MeSH] OR Cost Analysis[MeSH] OR Validation Study[Publication Type]). This
12 systematic review was registered on PROSPERO (registration number CRD42022310941).

13

14 Inclusion and exclusion criteria

15 Based on the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)
16 statement¹⁴ the Patient-Intervention-Comparison-Outcome-Study design (PICOS) approach
17 was used to further select only double-blinded, placebo-controlled RCTs comparing the
18 efficacy and/or safety of antimuscarinics plus alpha-blockers versus alpha-blockers and placebo
19 to treat BPH patients with storage symptoms. Thus, open-label and retrospective studies as well
20 as case reports were excluded from this systematic review. RCTs evaluating antimuscarinics in
21 patients with storage symptoms related to idiopathic or neurogenic overactive bladder
22 syndrome were also excluded. Diagnosis of storage symptoms had to be based on either patient-
23 reported symptoms, such as frequency, or urgency, or confirmed by urodynamic studies.
24 Intervention drugs had to be explicitly labeled as tolterodine, fesoterodine, propiverine,
25 trospium, darifenacin, solifenacin, or oxybutynin, and studies involving non-oral

1 administrations of antimuscarinics were excluded. Finally, reports had to evaluate the efficacy
2 and/or safety of antimuscarinics, and those focusing on patient adherence or cost-effectiveness
3 were excluded.

4

5 **Systematic review process**

6 After the removal of duplicates, 496 reports were independently reviewed by two authors (L.L.
7 and U.P.) based on title and/or abstract screening to further select 52 studies for full-text
8 assessment. Any disagreement regarding study inclusion was resolved by discussion between
9 the two reviewers (L.L. and U.P.) and a third reviewer (T.S.) was asked to decide if no
10 consensus could be reached. Based on the aforementioned inclusion and exclusion criteria, a
11 final cross-checked selection was made of 12 RCTs published between 2005 and 2016.^{9-12, 15-23}
12 Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) was
13 used to select the studies during the systematic review process, as presented in the PRISMA
14 flowchart (**Figure 1**).

15

16 **Data extraction**

17 Data were independently extracted from all included studies by two authors (L.L. and U.P.)
18 with subsequent cross-checks to ensure their accuracy. Covidence systematic review software
19 was used to create a standardized data extraction form that was created *a priori*. First, study-
20 level data included the reference, study design, study period, country, overall number of patients
21 included, as well as inclusion and exclusion criteria. Second, patient-level data included mean
22 IPSS and age at inclusion. Third, treatment-level data included the drug and dosage
23 administered and the sample size of each intervention group. It should be noted that when
24 several antimuscarinic dosages were evaluated in the included RCTs, only data from the highest
25 dosage group were extracted. Fourth, efficacy outcomes included the number of urgency and

1 micturitions per day as well as IPSS QoL scores. Finally, safety outcomes included the PVR,
2 and the occurrence of adverse events, such as acute urinary retention (AUR), dry mouth,
3 constipation, and dizziness.

4

5 **Risk of bias assessment**

6 Two reviewers (L.L. and U.P.) independently assessed the risk of bias (RoB) in each included
7 study using the Cochrane Collaboration RoB tool, which includes seven domains for RCTs:
8 random sequence generation, allocation concealment, participant and staff blinding, outcome
9 assessment blinding, incomplete outcome data, selective reporting, and other sources of bias.²⁴
10 Any disagreement with regards RoB assessment was resolved by discussion between the two
11 reviewers (L.L. and U.P.) and a third reviewer (T.S.) was asked to decide if no consensus could
12 be reached.

13

14 **Data and statistical analyses**

15 A narrative synthesis of included RCTs was first performed. Descriptive statistics were used to
16 summarize extracted baseline study-, patient- and treatment-level data. Continuous outcomes
17 were described using raw mean differences and standard deviation, or alternatively, median and
18 interquartile ranges, whereas frequencies and proportions were used for categorical outcomes.
19 A similar methodology was used to report subjective outcomes for efficacy including QoL data.

20 In addition, meta-analyses were also performed of objective efficacy and safety data.
21 Our primary endpoint was the efficacy of antimuscarinics using mean changes in urgency and
22 frequency. Raw effect size data in the form of means and standard deviations of the two groups
23 were pooled to calculate standardized mean differences (SMDs). The secondary endpoint was
24 the safety of antimuscarinics including mean changes in PVR calculated using similar a SMD
25 methodology, but also the risk of AUR, dry mouth, constipation, and dizziness calculated using

1 risk ratios (RRs) with the Mantel-Haenszel method to evaluate the weights of studies for binary
2 outcome data. A random effect model was used to calculate these pooled estimates of treatment
3 effects and their 95% confidence intervals [CIs]. Between-study heterogeneity was assessed
4 using the Higgins and Thompson's I^2 statistic, which quantifies inconsistency across trials to
5 assess the impact of heterogeneity on the meta-analyses. If substantial heterogeneity was
6 observed ($I^2 > 50\%$), we attempted to determine possible reasons by examining individual trials
7 and subgroup characteristics to check for outlier studies. Sensitivity analyses were further
8 conducted by excluding outlier studies to evaluate the robustness of the pooled effect estimate.
9 Meta-regression analyses were performed for clinically relevant covariates to further explore
10 potential reasons for heterogeneity and to assess if differences in true effect sizes could be
11 explained outcomes at the study level. Finally, Funnel plots were used to explore bias in the
12 results of meta-analyses.²⁵ Egger's test was used to assess funnel plot asymmetry for continuous
13 outcomes with intervention effects measured as mean differences.²⁶ All meta-analyses were
14 performed using open-source R statistical software v.4.0.4 (R Foundation for Statistical
15 Computing, Vienna, Austria).

16

17

1 **RESULTS**

2 **Overall characteristics of the included studies**

3 Overall, 12 RCTs were included^{9-12, 15-23} among which two types of patient populations were
4 identified. In six studies, patients without prior BPH treatment were randomized to alpha-
5 blockers alone or in combination with antimuscarinics.^{9, 11, 12, 18-20} Of the remaining studies, five
6 included patients with persistent storage symptoms despite prior treatment with alpha-
7 blockers^{10, 16, 17, 21, 23} and one study did not report whether or not alpha-blockers were used
8 before randomization.²² Several RCTs reported the results for each of the antimuscarinics
9 tolterodine, solifenacin, and propiverine, while two single trials reported the results for
10 oxybutynin and fesoterodine. The sample size in the overall population was 4634 patients of
11 whom 2273 received tamsulosin alone and 2361 received alpha-blockers in combination with
12 antimuscarinics. The overall characteristics of the included studies are shown in **Table 1**.

13

14 **Baseline patient characteristics**

15 At inclusion, the lower age limit ranged between 40- and 50-years, daily urgency and frequency
16 had to be >1–3 and 8, respectively, and the upper limit of PVR varied from 50–200 ml. Mean
17 IPSS at inclusion ranged from 13.3–29.2 and the primary endpoint was assessed at 12 weeks in
18 most studies. The baseline study characteristics are presented in **Table 1**.

19

20 **Risk of bias assessment**

21 Despite the high level of evidence of these placebo-controlled RCTs, more than half of the
22 studies had a high or uncertain RoB regarding either random sequence generation, allocation
23 concealment, blinding of participant and personnel, or blinding of outcomes. In these reports,
24 the method of randomization was often not described precisely leading to uncertainty regarding
25 the RoB. **Figure 2** shows the RoB assessment for the included studies.

1

2 **Efficacy outcomes**

3 *Subjective measures*

4 IPSS QoL scores were reported in five trials including 1656 patients. The raw mean reduction
5 of IPSS QoL ranged between -1.08 and -0.25. However, the meta-analysis showed no
6 significant reduction in the IPSS QoL score with the use of antimuscarinics (SMD= -0.48
7 [95%CI: -1.05; 0.09]; $I^2=86%$ $p=0.08$; **Figure 3A**). The substantial between-study
8 heterogeneity was caused by the RCTs of Lee et al. and Cai et al. reporting extreme effects.^{9,20}
9 Meta-regression analysis showed that previous treatment with alpha-blockers did not influence
10 the study effect size ($p=0.7$) and that 94% of the data variability could be attributed to the
11 remaining between-study heterogeneity.

12

13 **Objective efficacy outcomes**

14 *Urgency*

15 Overall, eight RCTs including 3602 patients evaluated the impact of antimuscarinics on
16 urgency.^{10-12, 16-18, 20, 23} The raw mean reduction in urgency episodes ranged from 0 to -1.4 per
17 24 h. However, the meta-analysis showed no significant reduction in the number of urgency
18 episodes per 24 h with the use of antimuscarinics (SMD= -0.25 [95%CI: -0.68; 0.19]; $I^2=88%$
19 $p=0.2$; **Figure 3B**). The substantial between-study heterogeneity was caused by the RCT of Lee
20 et al. reporting an extreme effect.²¹ After excluding this study, the sensitivity meta-analysis
21 showed a SMD= -0.07 [95%CI: -0.12; -0.02]; $p=0.01$, $I^2=0%$.

22 Meta-regression analysis showed that previous treatment with alpha-blockers did not
23 influence the study effect size ($p=0.35$) and that 95% of the data variability could be attributed
24 to the remaining between-study heterogeneity.

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Frequency

Overall, eight RCTs including 3398 patients evaluated the impact of antimuscarinics on frequency.^{10-12, 16, 17, 19, 20, 23} The raw mean reduction in frequency episodes ranged between -0.2 and -1.1 per 24 h. The meta-analysis confirmed the significant reduction in number of frequency episodes per 24 h with the use of antimuscarinics (SMD= -0.19 [95%CI: -0.37; -0.01]; p=0.045, I²=63%; **Figure 3C**).

The substantial between-study heterogeneity was caused by the RCT of Lee et al. reporting an extreme effect.²¹ After excluding this study, the sensitivity meta-analysis showed a SMD= -0.10 [95%CI: -0.19; -0.02]; p=0.01, I²=0%.

Meta-regression analysis showed that previous treatment with alpha-blockers did not influence the study effect size (p=0.20) and that 67% of the data variability in could be attributed to the remaining between-study heterogeneity.

Risk of publication bias for urgency and frequency

Funnel plots for urgency and frequency including all studies from each meta-analyses showed asymmetry (p=0.07 and p<0.01 for the Egger's test for funnel plot asymmetry, respectively; **Figure 4**).

Objective safety outcomes

Post-void residual and acute urinary retention

Overall, seven RCTs including 2003 patients evaluated the impact of antimuscarinics on PVR.^{9, 10, 16, 19, 21-23} The meta-analysis showed a statistically significant increase in PVR with the use of antimuscarinics (SMD=0.26 [95%CI: 0.13; 0.39]; p<0.01, I²=26%; **Figure 5A**). However, the raw mean increase in PVR ranged from 1–25.5 mL which was not considered clinically

1 significant. Nevertheless, the impact of antimuscarinics on the risk of AUR was evaluated in
2 nine RCTs,^{9, 11, 12, 16-19, 21, 23} which showed an increased relative risk ranging from 0–14.5. The
3 meta-analysis confirmed the significantly increased risk of AUR with the use of antimuscarinics
4 (RR=3.26 [95%CI: 1.35; 7.86]; p=0.02, I²=0%; **Figure 5B**).

5

6 *Other adverse events*

7 Overall, the risk of dry mouth, constipation, and dizziness was evaluated in 11,^{9-12, 15-19, 21-23} 10,
8 ^{9-12, 16-19, 22, 23} and four^{9, 11, 18, 19}RCTs, respectively. Contradictory findings were observed for all
9 these side-effects with the risk of dry mouth, constipation, and dizziness ranging from 0.94–
10 34.2, 0.97–16.1, and 0.48–8.3, respectively. The meta-analyses showed a significantly
11 increased risk of dry mouth (RR=3.10 [95%CI: 1.71; 5.62]; p<0.001, I²=76%; **Figure 5C**),
12 constipation (RR=3.52 [95%CI: 2.23; 5.54]; p<0.001, I²=0%; **Figure 5D**), and dizziness
13 (RR=1.02 [95%CI: 0.22; 4.69]; p=0.9, I²=34%; **Figure 5E**) with the use of antimuscarinics.
14 The substantial between-study heterogeneity regarding the side-effect dry mouth was caused
15 by the VICTOR trial reporting extreme effects. After excluding this study, the sensitivity meta-
16 analysis showed RR=3.03 [95%CI: 2.30; 4.00]; p<0.001, I²=0%. Meta-regression analysis for
17 dry mouth showed that previous treatment with alpha-blockers did not influence the study effect
18 size (p=0.22) and that 73% of the variability in our data could be attributed to the remaining
19 between-study heterogeneity. Finally, the risk of treatment interruption due to adverse events
20 assessed in nine RCTs including 3810 patients was higher for those treated with antimuscarinics
21 (RR=1.74 [95%CI: 1.27; 2.38]; p<0.01, I²=0%, **Figure 5F**).

22

1 DISCUSSION

2 This systematic review and meta-analysis evaluated the efficacy and safety of antimuscarinics
3 to treat storage symptoms in men with BPH. Our principal finding was that treatment with
4 antimuscarinics was not associated with any substantial benefit on urgency and frequency over
5 established treatment with alpha-blockers. Furthermore, there were more side-effects with
6 antimuscarinics compared to alpha-blockers when the data were sufficient to have a pooled
7 comparison.

8 The main strength of this systematic review is that it addresses a clinically relevant issue
9 that most urologists frequently encounter in their daily practice. It is the first review to
10 specifically evaluate the efficacy of antimuscarinics on storage symptoms in patients with BPH.
11 Indeed, most reviews have evaluated the efficacy of antimuscarinics on total IPSS or Qmax,^{13,}
12 ²⁷ but these parameters do not specifically assess storage symptoms. It was deemed necessary
13 to fill this gap by evaluating the effect of antimuscarinics on frequency and urgency in a
14 systematic review with a stringent methodology following a pre-established protocol and
15 PRISMA criteria, including randomized, placebo-controlled studies with a high level of
16 evidence. Most previous systematic reviews included open-label studies and did not include a
17 rigorous assessment of the quality of evidence beyond the study design, which despite
18 randomization was often subject to measurement bias.

19 Tolterodine and solifenacin were the most frequently studied agents in this review and
20 were evaluated in five and four RCTs, respectively. Their efficacy at reducing urgency and
21 micturition was limited. The maximum raw mean reduction of urgency and frequency were
22 -1.4 and -1.1 episodes per day, respectively. As shown previously in the setting of idiopathic
23 overactive bladder,³⁰ the differences in efficacy between the types of drugs were minimal and
24 the overall efficacy was limited, despite statistically significant but small differences when
25 comparing the efficacy of the drugs with placebo.

1 A meta-analysis of urgency and frequency showed substantial between-study
2 heterogeneity. The examination of individual trials and subgroup characteristics identified Lee
3 et al. 2011²² as an outlier for both outcomes, mainly because of its wide confidence interval.
4 Further sensitivity analyses excluding outliers reported statistically significant results showing
5 a non-clinically relevant reduction of urgency (SMD=0.07). Six studies included patients
6 without prior BPH treatment^{9, 11, 12, 18-20} while five studies included patients with persistent
7 storage symptoms despite prior treatment with alpha-blockers.^{10, 16, 17, 21, 23} However, meta-
8 regression analyses showed that previous treatment with alpha-blockers did not influence the
9 study effect size with regard to urgency and frequency.

10 The risk of publication bias estimation through funnel plots and Eger's test showed
11 significant asymmetry. The asymmetry was particularly observed for frequency ($p < 0.01$) with
12 studies seeming to be missing in areas of non-significance, which could be due to reporting
13 bias. Several factors might explain the limited observed efficacy of antimuscarinics: first, the
14 heterogeneity between studies regarding the selection criteria, and particularly the difference in
15 severity of storage symptoms at baseline, complicates the comparison. Whereas the ADAM,
16 VICTOR, Lee et al. 2011, and Lee et al. 2005 studies^{11, 16, 20} required that eligible subjects had
17 ≥ 1 urgency episodes per 24 h at baseline, the TIMES, Sener et al. 2013, and 2012 Kaplan et al.
18 studies^{17, 18, 22} required ≥ 3 urgency episodes per 24 h at baseline. Second, differences between
19 alpha-blocker treatments may also be accountable for the differences in efficacy between
20 studies. Tamsulosin was the alpha-blocker prescribed in the majority of studies, but other
21 studies included patients with other alpha-blockers prescribed before study initiation. Third,
22 variability in the prescribed dose of antimuscarinic and, in particular, the difference in protocol
23 with flexible-dose escalation (VICTOR and Kaplan et al. 2012 studies^{11, 17}) or fixed-dose
24 studies may also account for the variation in treatment efficacy. The variability in efficacy
25 associated with the higher rate of side-effects could lead to a rethink of the prescribing model

1 by moving towards on-demand treatment, which could be useful to maximize patient
2 compliance and have a reasonable ratio between benefit and adverse effects.

3 The pathophysiological mechanism leading the patient to have urgency may vary from
4 patient to patient and may also explain the differences in efficacy of symptomatic treatment
5 with antimuscarinics. When urgency is related to an irritative spike in the bladder mucosa
6 triggering uninhibited detrusor contractions, the expected benefit of antimuscarinics may be
7 high. In other patients, sphincter insufficiency due to fatigue and age-related amyotrophy can
8 lead to urine passage through the urethra and trigger an urge to urinate through a uretrovesical
9 reflex mechanism without real bladder hyperactivity. For these patients, the expected efficacy
10 of antimuscarinics would be quite limited. Identifying patients with muscarinic receptor
11 dysregulation resulting in increased sensitivity to acetylcholine due to chronic obstruction
12 warrants further research. Understanding which patients are likely to respond, or not, could
13 significantly shift the outcomes of future similar studies.

14 One of the main concerns about prescribing antimuscarinics in patients with BPH is the
15 risk of AUR and increased PVR. In this meta-analysis, we found a significant, yet not clinically
16 relevant, PVR mean difference for patients treated with antimuscarinics (SMD=13.3 [95%CI:
17 5.2; 21.3]; $p<0.01$). However, most of these studies excluded patients with high PVR before
18 treatment. Therefore, these results are not transferable to BPH patients with significant PVR.
19 Notwithstanding the exclusion of patients with high PVR and the small difference in mean PVR
20 after treatment, the risk of AUR was increased more than threefold in patients treated with
21 antimuscarinics (RR=3.26 [95%CI: 1.35; 7.86]; $p=0.02$, $I^2=0\%$), but the overall incidence was
22 less than 3% in all trials.

23 Our results are consistent with those of a previous meta-analysis. Füllhase et al. reported
24 that add-on combination therapy, compared with alpha-blockers alone, showed a 9.2%
25 reduction in 24-h voiding frequency and a reduction of 1.1 urgency episodes per day.²⁷ In a

1 more recent meta-analysis, Dahm et al. evaluated the effect of add-on therapy with an
2 antimuscarinic on the mean change in IPSS score and IPSS QoL, but did not report any findings
3 regarding urgency or frequency. In this study, darifenacin, fesoterodine, solifenacin,
4 oxybutynin, tolterodine, and trospium were not associated with a significant improvement in
5 the IPSS score compared to the control group. Finally, a systematic review by Kaplan et al.²⁸
6 reported the results of the randomized, double-blind TIMES, ADAM, VICTOR, MacDiarmid
7 et al. studies and several other prospective studies,²⁹⁻³¹ and concluded that antimuscarinic plus
8 alpha-blocker therapy provided a significant benefit to men with BPH and storage symptoms.
9 However, this was a systematic review without any meta-analysis and the authors did not
10 provide detailed results on mean change in micturition or urgency. The meta-analysis conducted
11 in our study found a significant but small reduction in urgency and frequency. Although our
12 results are in line with current EAU and AUA guidelines,^{32, 33} which advocate cautious use of
13 antimuscarinics in patients with high PVR, we also relativize the observed clinical effectiveness
14 of antimuscarinics on storage symptoms. The level of evidence on which the recommendations
15 were based was intermediate (i.e., Level 2) because it was partly derived from open-label
16 studies and post-hoc analysis. Our meta-analysis of high-level evidence studies should be useful
17 in tempering these recommendations and in guiding patients towards on-demand treatment
18 while warning of the risk of side-effects and variable efficacy.

19 Despite the aforementioned strengths and the add-on value to the existing literature, this
20 study is not devoid of limitations. First, the placebo group cannot be considered a no-treatment
21 group in these studies, especially because patients were required to complete a voiding diary.
22 The latter provides insight into behavioral adjustments that can improve symptoms by educating
23 patients about their voiding habits. Second, the primary endpoint was measured at 12 weeks for
24 most studies. Thus, there is no clear evidence that the efficacy of treatment, however limited,
25 persists beyond this period. Similarly, there is no evidence that the safety profile and side-

1 effects remain the same after 3 months of treatment in patients with BPH. However, since
2 bladder alterations due to chronic obstruction may take months to completely resolve, studies
3 with longer follow-up may yield different results. Third, the current study did not identify any
4 predictive factors of efficacy of antimuscarinic therapy in patients with BPH. Previous post-
5 hoc analyses showed that a combination therapy with tolterodine and tamsulosin was effective
6 in subjects regardless of whether their baseline prostate size or serum prostate-specific antigen
7 level was above or below the respective study median.^{34, 35} Fourth, some studies were not
8 designed specifically to measure the improvement in frequency and urgency as main endpoints
9 and this might lead to possible bias. Finally, the variability between inclusion and exclusion
10 criteria in all the studies included leads to heterogeneity in the severity of baseline symptoms,
11 which complicates the comparison of raw mean reduction in the main outcomes of interest.

12

13 **CONCLUSION**

14 Treatment with antimuscarinics was not associated with a short-term substantial reduction of
15 urgency and frequency over established treatment with alpha-blockers. Furthermore, there were
16 also more adverse events with antimuscarinics than with alpha-blockers when the data were
17 sufficient for a pooled comparison. Clinicians should be aware of these findings in order to
18 explain to their patients the expected limited short-term benefit of antimuscarinic therapy on
19 storage symptoms and the potential side-effects of this treatment.

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1 **Data availability Statement**

2 The data sets generated during and/or analyzed during the current study are available from the
3 corresponding author on reasonable request.

4

5 **Figure Legends**

6 **Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses**
7 **(PRISMA) flowchart.**

8 **Figure 2. Risk of bias assessment.**

9 **Figure 3. Comparison of alpha-blockers vs. alpha-blockers plus antimuscarinics on (A)**
10 **IPSS QoL, (B) urgency/24 h, and (C) and micturition/24 h.**

11 QoL: quality of life; A negative SMD means that the experimental group has a lower mean
12 score than the control group (i.e., a reduction in the assessed outcome for the antimuscarinic
13 group)

14 **Figure 4. Funnel plot for estimation of publication bias risk for urgency and frequency**

15 **Figure 5. Comparison of alpha-blockers vs. alpha-blockers plus antimuscarinics on (A)**
16 **mean increase in post-void residual (PVR), (B) risk of acute urinary retention (AUR), (C)**
17 **risk of dry mouth, (D) risk of constipation, (E) risk of dizziness, and (F) treatment**
18 **interruption due to adverse events.**

19 A negative SMD means that the experimental group has a lower mean score than the control
20 group (i.e., a reduction in the assessed outcome for the antimuscarinic group)

21