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Efficacy of the Automated Mechanical Repositioning Chairs Treatment for Patients with Benign Paroxysmal Positional Vertigo

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Abstract

Objective: To examine the efficacy of the automated mechanical repositioning chairs compared to canalith repositioning maneuvers for elderly patients with benign paroxysmal positional vertigo.

Methods: A retrospective study included 969 patients with BPPV who were first diagnosed at Beijing Chaoyang Hospital, Capital Medical University between January 1, 2020 and December 31, 2020. Patients were followed up for one year. Demographics, disease status, treatment, and various outcomes were collected through medical record reviews and follow-up interviews.

Results: Based on the criteria for evaluating treatment efficacy using objective and subjective indicators, BPPV patients treated with automated mechanical repositioning chair therapy showed a significantly better prognosis and lower recurrence rates.

Conclusion: Automated mechanical repositioning chair therapy is an effective approach for BPPV treatment, with advantages over conventional manual canalith repositioning procedures.

Keywords

Benign paroxysmal positional vertigo, Medical records, Retrospective studies

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Introduction

Benign paroxysmal positional vertigo (BPPV) is the most common cause of peripheral vertigo[1]. According to the widely accepted canalolithiasis theory, BPPV is believed to be caused by the dislocation of the otoconia in the semicircular canals. Effective approaches for managing BPPV, such as canalith repositioning maneuvers (CRMs) and other bedside physical therapies, have proven to alleviate symptoms rapidly[2, 3]. Early treatment can shorten the duration of the disease and improve the quality of life[4]. This maneuver involves flexing, extending, and rotating the patient's neck. However, during the examination and treatment process, patients need to change their position repeatedly[5-8]. In recent years, automated mechanical repositioning chair (AMRC) has been developed for diagnosing and treating patients with a typical case history of BPPV. AMRC allows unlimited movement while maintaining the body's natural anatomical alignment. Patients are securely seated and rotated 360° in all directions, eliminating the need for neck and back rotation during therapeutic and diagnostic maneuvers. Infrared videonystagmography goggles are used for monitoring eye movement simultaneously with rotation.

Some studies have sought to evaluate the effectiveness of modified AMRC and conventional CRMs for treating BPPV. These studies, which examined treatment frequency, remission rate, recurrence rate, and other indicators, generally support AMRC as an effective treatment method for BPPV[9-20]. However, most of these studies only involved a single treatment group and did not compare the efficacy of AMRC with conventional manual canalith repositioning procedures (CRP) [9, 13-17, 19, 20]. Only four studies included a control group, which yielded inconsistent results[10-12, 18]. Some studies suggested that the efficacy of AMRC was either equivalent to or not superior to the conventional manual CRP for treating BPPV[11, 12]. One

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study demonstrated that AMRC was significantly superior to conventional manual CRP in treating unilateral posterior semicircular canal BPPV, both in the short-term and long-term[18]. Another study showed similar efficacy between the two treatment methods for mono-canal BPPV, but the AMRC was more effective than conventional manual CRP for treating multi-canal BPPV[12]. However, these studies have certain limitations. Some studies had small sample sizes, lacking the statistical power for comparisons and subgroup analysis[10-12]. Some studies only included specific subtypes of BPPV, providing evidence for the effectiveness of AMRCs in only some subtypes[11, 18]. One study solely provided descriptive statistical results without statistical tests[10]. Overall, the efficacy of AMRCs in treating BPPV compared to CRMs remains inconclusive and necessitates further investigation with valid statistical analysis. This study aimed to evaluate the efficacy of the AMRCs compared to CRMs among older BPPV patients.

Materials and methods

Subjects

This retrospective study included 969 patients with BPPV who were first diagnosed in Beijing Chaoyang Hospital, Capital Medical University, between January 1, 2020 and December 31, 2020, with a one-year follow-up period. Patients' BPPV characteristics, treatment, and recurrence data were collected through medical record reviews and phone interviews during follow-up.

Inclusion criteria were as follows: (1) age over 60 at the time of initial enrollment; (2) a diagnosis of BPPV according to the 2017 Chinese Medical Association guidelines, characterized by recurrent, transient vertigo or dizziness (usually lasting under 1 minute)

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triggered by head position changes relative to the direction of gravity, with accompanying vertigo and characteristic positional nystagmus evident during the position test, and positive results in the Dix Hallpike test and/or roll test; (3) patients' first diagnosis and subsequent treatment conducted exclusively in Chaoyang Hospital, Capital Medical University, without transfer treatment.

Exclusion criteria were as follows: (1) presence of complications, including acute episodes of various cardiovascular diseases, orthostatic hypotension, uncontrolled hypertension, cerebral infarction, cerebral hemorrhage, severe cardiovascular disease post-surgery, and venous thrombosis; (2) co-occurrence of central vertigo, vestibular migraine, vestibular paroxysmia, Ménière's disease, vestibular neuritis, labyrinthitis, and superior canal dehiscence syndrome; (3) concurrent severe depression, anxiety disorders, severe mental disorders, ophthalmic diseases, claustrophobia, upper gastrointestinal bleeding, large intrahepatic vascular malformation, severe lumbar and cervical spine diseases; (4) Patients with secondary or recurrent BPPV.

This is a retrospective study without randomisation. The selection for treatment is based on the patient's underlying medical conditions at baseline.

Informed consent was obtained from all participants. This study has been approved by the Ethics Committee of Beijing Chaoyang Hospital, Capital Medical University (Approval No. 2023-KE-314).

Examined variables

Demographics, disease status, treatment, and various outcomes were collected. Demographic characteristics included age, gender, and medical history. The disease characteristics included the affected semicircular canals. Outcome measures included assessments of symptoms, the

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presence of residual symptoms and one-year recurrence rates. Assessments of symptoms were conducted on patients one day and one month after initial treatment. Patient treatment outcomes were categorized as “cured or relieved” and “failure”. Cure or relieve was defined as the absence or relief of positional nystagmus and positional vertigo diagnosed by the physician. Recurrence within one year was defined as BPPV reoccurring after one year following successful treatment. Residual symptoms after being cured referred to the presence of nonspecific subjective symptoms, such as non-rotational dizziness, unsteadiness, and lingering sensations, which were diagnosed as residual symptoms, after the successful treatment, even though patients no longer exhibited positional nystagmus and positional vertigo. The residual symptom variable included symptom persistence for 1–3 days, 4–7 days, or longer than one week.

Statistical analysis

We included ten covariates that were likely to impact treatment allocation, including gender, age, and the presence of underlying medical conditions at baseline (such as heart disease, hypertension, hyperlipidemia, diabetes, lacunar infarction, cervical spondylosis, restricted pain, and carotid plaque). A notable imbalance in the baseline covariates within the original dataset was observed, as illustrated in Figure 1 and Table 1. For instance, the patients in the AMRC group are older than those in the manual CRM group. To address this imbalance, we employed the R package MatchIt for matching and subsequent inference.

Specifically, coarsened exact matching was utilized to balance the baseline covariates and mitigate the impact of potential confounding variables. Following this matching process, all standardized mean differences for the covariates were below 0.1, as shown in Figure 2 and

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Table 2, indicating an acceptable level of balance. The final sample size after matching was 452 patients.

To estimate the treatment effect along with its associated standard error, we employed a regression model that included treatment variables, relevant covariates, and their interactions as predictors. We utilized the lm() function for continuous outcomes and the glm() function for binary outcomes. Furthermore, the comparisons() function was employed to execute g-computation within the matched sample, allowing us to estimate the ATE. We employed a cluster-robust variance estimation, with matching stratum membership serving as the clustering variable.

Our analysis included various outcome measures, including assessments of symptoms after treatment (at 1 day and during long-term follow-up), the presence of residual symptoms (within 1–3 days, 4–7 days, and beyond 7 days) and one-year recurrence rates,.

In addition to the primary analysis, we conducted subgroup analyses in two common subgroups: patients with unilateral mono-canal BPPV (including 931 individuals) and those with posterior canal BPPV (including 770 individuals). The same matching and inference procedures are employed. Other subgroups (multi-canal or non-posterior) were excluded from subgroup analysis due to their small sample size, which precluded meaningful comparisons.

Results and analysis

Assessments of symptoms

We assessed patient outcomes following treatment at two time points: 1 day and 1 month after the initial treatment. At the 1-day mark, 77.5% of patients in the AMRC group reported being cured or relieved, which was comparable to the manual CRM group (74.2%, p=0.203). The

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estimated risk difference was 6.8%. After 1 month from the initial treatment, all patients in the AMRC group reported being cured or relieved, which was moderately higher than the manual CRM group (96%). The estimated risk difference was 4.4%, which did not reach statistical significance (p=0.061).

Residual symptoms and recurrence rate

We then examined the presence of residual symptoms. Within 1–3 days, 12.8% of patients in the AMRC group had residual symptoms, significantly lower than the manual CRM group (47.6%, p<0.001). The estimated risk difference was -27.1%. Within 3–7 days, 8.4% of patients in the AMRC group still had residual symptoms, significantly lower than patients in the manual CRM group (26.2%, p<0.001). The estimated risk difference was -25%. Beyond 7 days, 4.8% of patients in the AMRC group had residual symptoms, compared to 9.3% in the manual CRM group. The estimated risk difference was -4.6%, but this difference did not reach statistical significance (p=0.163).

We also compared the recurrence rates between the two treatment groups. The recurrence rate was significantly lower in the AMRC group than the manual CRM group (29.5% and 43.1%, respectively, p=0.023). The estimated risk difference was -12.9%. Therefore, we conclude that AMRC treatment significantly reduced the rates of residual symptoms and recurrence when compared to the manual CRM group.

The results of above analyses are presented in Tables 3.

Subgroup analysis

We conducted subgroup analyses for 436 matched samples with unilateral mono-canal BPPV and 334 matched samples with posterior canal BPPV. The results of these analyses are

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presented in Tables 4 and 5. These findings align with our primary analysis, reinforcing the robustness of our conclusions across different patient populations.

Discussion

This study aimed to compare the treatment outcomes in elder patients with BPPV and investigate whether there are differences in treatment efficacy between AMRCs and conventional manual CRP. The results revealed a significant difference in BPPV prognosis between the two treatment methods when evaluating treatment efficacy based on both objective and subjective indicators. Patients treated with AMRC therapy experienced fewer residual symptoms and lower recurrence rates. These findings align with the results of previous studies. For example, a study conducted by Jun Tan et al.[18] included a total of 165 patients with unilateral posterior canal BPPV and evaluated the long-term and short-term effectiveness of AMRCs and conventional manual CRP. The results indicated that one week after the first treatment, patients in the AMRC group demonstrated significantly better treatment outcomes compared to the conventional manual CRP group. At 4 weeks and 3 months after the initial treatment, the AMRC group required significantly fewer treatment sessions compared to the conventional manual CRP group. Another study by AKA Yamout[10] assessed the effectiveness of patients using the Dizziness Handicap Inventory and Visual Analog Scale questionnaires, demonstrating the superiority of AMRC over conventional manual CRP in treating multiple canal BPPV.

However, this study found no significant differences in the cure rate between AMRCs and conventional manual CRP in BPPV patients, which aligns with findings in some previous studies. For example, Alexander Schuricht et al[12]. reported that after one treatment session,

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there were no significant differences in the cure rate or the total number of treatment sessions between the AMRC group and the conventional manual CRP group. Similar results were observed in the study by Mine Baydan-Aran et al., which focused solely on patients with multi-canal BPPV[11]. The absence of significant differences in the cure rate and number of treatment sessions between the two methods may be attributed to their overall high cure rates. Previous studies on the use of AMRC therapy for treating BPPV have yielded contradictory conclusions regarding its efficacy, primarily due to inadequate statistical comparison. Some studies lacked control groups or relied solely on descriptive statistics without conducting statistical tests, and many had very small sample sizes[8-12, 17, 18]. Furthermore, due to the distinct characteristics of the two methods, a direct comparison could introduce bias. Patients who opt for AMRC treatment may have specific characteristics, such as mobility limitations or restricted neck movement. Therefore, these two patient populations are more likely to exhibit selection bias.

In contrast, this study evaluated and compared the effectiveness of AMRC and conventional manual CRP using a large sample of Chinese individuals. This is the first study to employ coarsened exact matching to mitigate data bias and confounding variables, allowing for a more reasonable comparison between the two groups. Because the baseline characteristics of the two groups are likely different and cannot be controlled in advance in a retrospective study, the use of coarsened exact matching can largely reduce the bias caused by the baseline population characteristics, making the results more reliable.

Although conventional manual CRP demonstrates relatively high success rates, 10–20% of patients who receive this treatment continue to experience symptoms even after multiple attempts[12]. In contrast, AMRCs allow precise positioning along the yaw and roll axes,

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enabling 360-degree rotation in two or three planes. Assisted by videonystagmography equipment, AMRCs can accurately monitor eye movements, assess nystagmus, and ensure that patients complete the treatment while remaining seated[21]. The diagnostic and treatment systems of AMRC are easy to operate, and the program can repeat the positioning operation at the same angle and speed, thereby minimizing the impact of physician proficiency and accuracy, which may contribute to better treatment outcomes. However, the cost of AMRC treatment in China is currently higher than that of conventional manual CRP, potentially resulting in higher overall treatment costs. Thus, further research is needed to explore its cost-effectiveness in BPPV treatment to aid decision-making for payers and providers.

The present study has certain limitations. Due to the low prevalence of certain BPPV subtypes and the single-center nature of the study, there were insufficient participants to conduct subgroup analyses for all BPPV subtypes. Moreover, this study was lacking in the measurement of patients' health states through self-reported scales such as the Dizziness Handicap Inventory and Visual Analog Scale, which are essential for evaluating patient quality of life. Also, the study data is derived from a single center. We cannot determine the valid treatment history of patients prior to the first admission or whether they sought treatment at other hospitals afterward. Such information can only be obtained through inquiries, and its accuracy cannot be guaranteed. Finally, variations in physician proficiency, including non-standardized rotation speeds and positional hold durations, may affect the effectiveness of conventional manual CRP. However, this study is limited by the number of physicians in the single center, and we cannot eliminate the influence of physician techniques, which could introduce potential bias.

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Conclusion(s)

In summary, both AMRC and conventional manual CRP show comparable treatment efficacy and number of treatment sessions for patients with BPPV. However, AMRC therapy results in lower rates of residual symptoms, indicating a better short-term prognosis and lower recurrence rates. Therefore, we conclude that AMRC therapy is an effective approach for BPPV treatment, offering advantages over conventional manual CRP.

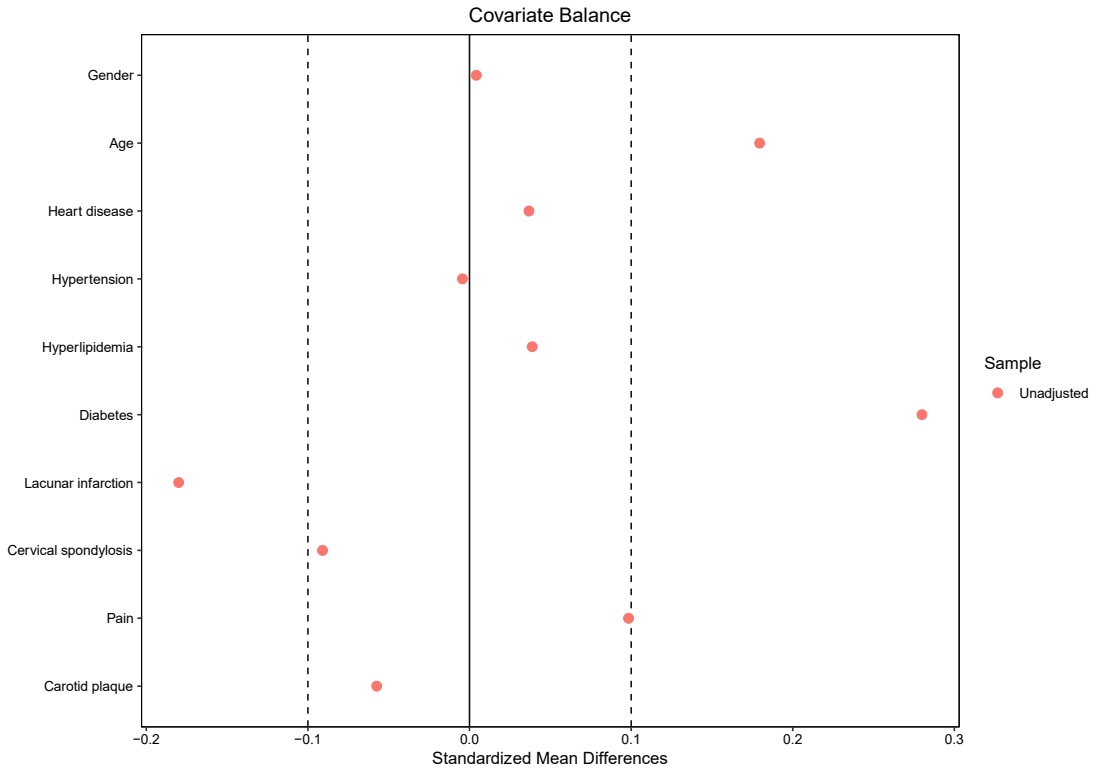

Fig.1

Covariate balance in the original sample. The X-axis corresponds to the standardized mean difference, while the Y-axis corresponds to each of the 10 baseline covariates. The solid line represents the zero point, indicating perfect balance. The standardized mean difference between the two dashed lines [-0.1, 0.1] indicates that the corresponding covariates are balanced[21].

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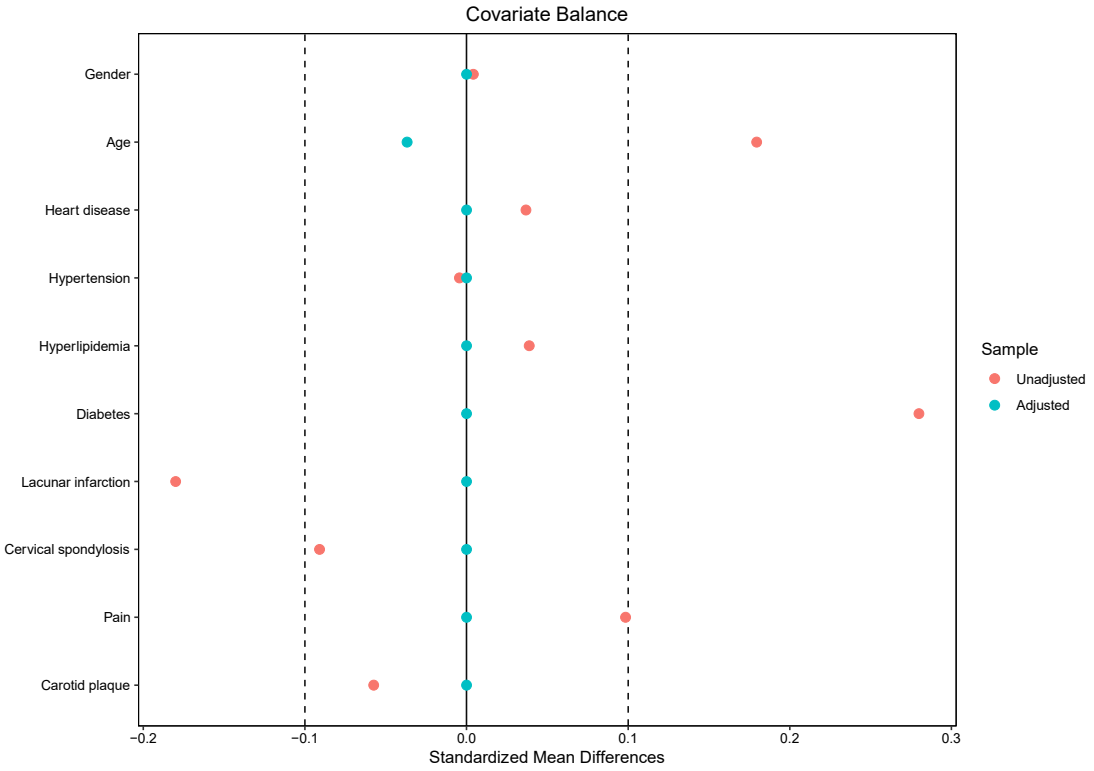

Fig.2

Covariate balance after matching. The X-axis corresponds to the standardized mean difference, while the Y-axis corresponds to each of the 10 baseline covariates. The solid line represents the zero point, indicating perfect balance. The standardized mean difference between the two dashed lines [-0.1, 0.1] indicates that the corresponding covariates are balanced[21]. The red dots represent samples that were not matched, while the blue dots represent matched samples.

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Tables and Charts

TABLE I

Covariate balance in the original sample. When the Standardized Means of Difference exceeds 0.1, the covariate is considered unbalanced [21]

COVARIATE	AMRC (N=477)	CRM (N=492)	STD MEAN DIFF
Gender	0.4	0.398	0.004
Age	68.331	67.096	0.18
Heart disease	0.109	0.098	0.037
Hypertension	0.396	0.398	-0.004
Hyperlipidemia	0.333	0.315	0.039
Diabetes	0.268	0.144	0.28
Lacunar infarction	0.161	0.228	-0.18
Cervical spondylosis	0.088	0.114	-0.091
Pain	0.149	0.114	0.098
Carotid plaque	0.321	0.348	-0.057

TABLE II

Covariate balance after matching. When the Standardized Means of Difference exceeds 0.1, the covariate is considered unbalanced [21]

COVARIATE	AMRC (N=227)	CRM (N=225)	STD MEAN DIFF
Gender	0.392	0.392	0
Age	65.806	66.059	-0.037
Heart disease	0.018	0.018	0
Hypertension	0.247	0.247	0
Hyperlipidemia	0.229	0.229	0
Diabetes	0.106	0.106	0
Lacunar infarction	0.088	0.088	0
Cervical spondylosis	0.013	0.013	0
Pain	0.013	0.013	0
Carotid plaque	0.229	0.229	0

TABLE III

Comparison of outcomes for matched sample

OUTCOME	AMRC (n=227)	CRM (n=225)	Estimate	p value
Assessment (1Day)	0.775	0.742	0.068	0.203
Assessment (1month)	1	0.96	0.044	0.061
Remains (1-3day)	0.128	0.476	-0.271	<0.001
Remains (4-7day)	0.084	0.262	-0.25	<0.001

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Remains (7+day)	0.048	0.093	-0.046	0.163
Recurrence	0.295	0.431	-0.129	0.023

TABLE IV

Comparison of outcomes for matched sample with unilateral mono-canal BPPV

Outcome	AMRC (n=220)	CRM (n=216)	Estimate	p value
Assessment (1Day)	0.791	0.773	0.051	0.354
Assessment (1month)	1	0.991	0.009	0.321
Remains (1-3day)	0.118	0.491	-0.293	<0.001
Remains (4-7day)	0.086	0.259	-0.255	<0.001
Remains (7+day)	0.045	0.074	-0.021	0.454
Recurrence	0.291	0.431	-0.143	0.016

TABLE V

Comparison of outcomes for matched sample with posterior canal BPPV

Outcome	AMRC (n=168)	CRM (n=166)	Estimate	p value
Assessment (1Day)	0.875	0.88	0.01	0.835
Assessment (1month)	1	0.958	0.042	0.102
Remains (1-3day)	0.113	0.458	-0.267	<0.001
Remains (4-7day)	0.071	0.253	-0.27	<0.001
Remains (7+day)	0.018	0.072	-0.057	0.084
Recurrence	0.28	0.422	-0.151	0.026

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