THE PLANET

Original Article

Pre-Extubation Blood Pressure Trends and Recovery Response in Hypertensive Patients

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ARTICLE INFO

Received: 19 July 2026
Accepted: 25 July 2026
Published Online: 28 July 2026

DOI:

Volume: 10, Number: 1, Page: 152-157

e-ISSN: 2789-5912
ISSN: 2617-0817

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ABSTRACT

Background: Extubation provokes sympathetic surge producing haemodynamic instability, disproportionately severe in patients with pre-existing hypertension and capable of precipitating arrhythmia, hypertensive crisis or delayed recovery. Blood pressure behaviour during the pre-extubation interval preceding the stimulus has received little study. **Objective:** To assess blood pressure trends during the pre-extubation period and their relationship to early recovery in hypertensive patients undergoing general anaesthesia. **Methods & Materials:** This prospective observational study was conducted in the Department of Anaesthesia, Analgesia and Intensive Care Medicine at Bangladesh Medical University, Dhaka, over twelve months. Sixty hypertensive patients undergoing surgery requiring endotracheal intubation were enrolled. Heart rate and arterial pressures were recorded at baseline, before induction, before extubation and up to fifteen minutes after extubation. Patients were classified as normotensive, hypotensive or hypertensive by intraoperative deviation from baseline and recovery was assessed using the Modified Aldrete Scoring System. **Results:** Mean age was 50.3 ± 7.5 years and 62% of patients were male. Following induction, 53.3% remained normotensive, 20.0% became hypotensive and 26.7% became hypertensive. Systolic, diastolic and mean arterial pressures diverged significantly between groups from the pre-extubation interval onward ($p = 0.001$). Extubation time was longer in the hypotensive (4.7 ± 0.5 minutes) and hypertensive (4.8 ± 0.8 minutes) groups than in the normotensive group (3.5 ± 0.4 minutes, $p = 0.001$) and Modified Aldrete scores were correspondingly lower in these two groups at every postoperative interval. **Conclusion:** Pre-extubation blood pressure behaviour predicts post-extubation stability and recovery quality in hypertensive patients, supporting closer haemodynamic surveillance during this window.

Keywords: *Hypertension, Extubation, Blood pressure, Recovery period, General anaesthesia.*

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INTRODUCTION

General anaesthesia is directed toward achieving a smooth induction, a stable intraoperative course and a rapid, uneventful recovery, with effective airway management central to patient safety throughout this trajectory [1]. Emergence, the terminal phase of anaesthesia, is inherently unpredictable, as the depressant effects of anaesthetic agents recede and consciousness, spontaneous ventilation, protective airway reflexes and responsiveness to verbal command are gradually restored [1,2]. Within this transition, extubation of the endotracheal tube constitutes the pivotal event, marking the point at which the patient resumes independent respiration [2].

Extubation, however, is not a passive procedural step but a substantial physiological challenge in its own right. Removal of the endotracheal tube provokes an abrupt sympathetic discharge that manifests as marked elevations in heart rate and arterial pressure [3]. In healthy individuals such perturbations are usually transient and self-limiting, but in patients with pre-existing hypertension the same stimulus can precipitate severe arrhythmia, heighten myocardial oxygen demand and, in the most serious instances, trigger a hypertensive crisis, cerebrovascular event or acute cardiac decompensation [4,5].

Hypertension remains one of the most prevalent cardiovascular disorders worldwide, affecting close to 1.4 billion people and contributing to roughly nine million deaths each year [6]. Its burden is disproportionately concentrated among surgical populations, particularly older adults and its prevalence as a recognized cardiovascular risk factor in patients aged 45 years and above undergoing non-cardiac surgery has risen sharply over the past decade [7]. In Bangladesh specifically, close to a quarter of adults between 18 and 69 years are hypertensive, a figure that climbs to almost half of those older than 60 years, while only a minority of affected individuals achieve adequate blood pressure control [6].

Hypertensive patients carry an appreciable risk of major perioperative cardiac morbidity, a risk that is attenuated chiefly through careful avoidance of wide swings in blood pressure and heart rate across the surgical course [8].

Contemporary perioperative guidelines emphasise that hypertensive patients face a heightened likelihood of arrhythmia, myocardial ischaemia, infarction, stroke and renal impairment and that haemodynamic fluctuation is essentially unavoidable across the surgical continuum, from intubation through surgical stimulation to emergence [9]. Among the several points at which such fluctuation occurs, the period surrounding extubation is especially precarious, since upper airway stimulation at this moment produces intense sympathetic activation superimposed on a cardiovascular system already primed by chronic hypertensive vascular change [3,8].

A variety of pharmacological strategies, including narcotic analgesics, deepened volatile anaesthesia, local anaesthetic agents, adrenoceptor antagonists and vasodilators such as diltiazem, lignocaine, esmolol, labetalol and nicardipine, have been trialled to blunt the pressor response associated with extubation, yet none has proved uniformly effective [4]. Much of the existing literature has concentrated on the haemodynamic disturbance associated with induction and intubation, leaving the pre-extubation interval, the transitional period between anaesthesia and wakefulness that precedes airway manipulation, comparatively under-examined. A clearer characterization of blood pressure behaviour during this window could offer clinicians an opportunity to intervene proactively rather than reactively, thereby blunting the subsequent extubation response before it fully develops.

Precise regulation of heart rate and blood pressure through the extubation period is a recognized determinant of favourable perioperative outcome in hypertensive patients [10] and the recovery trajectory that follows, commonly captured using the Modified Aldrete Scoring System, provides an objective index of how well this transition has been managed [11]. Building on this premise, the present study was designed to characterise blood pressure trends across the pre-extubation and immediate post-extubation period in a cohort of diagnosed hypertensive patients and to examine how these trends relate to early recovery response, with the intention of informing more individualized extubation practice in this vulnerable population.

Objective of the study

The objective of this study was to assess blood pressure trends during the pre-extubation period and their impact on the recovery response in hypertensive patients undergoing general anaesthesia.

METHODS & MATERIALS

This was a prospective observational study conducted in the operation theatres under the supervision of the Department of Anaesthesia, Analgesia and Intensive Care Medicine, Bangladesh Medical University, Dhaka, Bangladesh, over a twelve-month period from April 2024 to March 2025. Sixty hypertensive patients undergoing surgery requiring endotracheal intubation were included in the study.

Selection Criteria:

Participants were recruited by purposive sampling from among diagnosed hypertensive patients admitted for elective surgery, following assessment during the pre-anaesthetic checkup.

Inclusion criteria:

- Known and diagnosed hypertensive patients on antihypertensive medication undergoing elective surgery under general anaesthesia requiring endotracheal intubation.
- Age between 31 and 65 years.
- Weight between 40 and 75 kg.
- ASA physical status Class II or Class III.
- Mallampati Class I or Class II airway.
- Surgery of more than one and less than three hours duration.

Exclusion criteria:

- ASA physical status Class IV or above.
- Severe systemic disease, including high-risk cardiac conditions (severe valvular heart disease, symptomatic congenital heart disease, heart failure), or significant pulmonary, renal or hepatic disease.
- Morbid obesity.
- Pregnancy.
- Documented hypersensitivity to anaesthetic agents required for general anaesthesia.

Study Procedure:

All patients received 7.5 mg of oral midazolam as premedication and their routine antihypertensive medications were continued through the morning of surgery. On arrival in the operating theatre, an intravenous cannula was inserted and standard monitoring, including pulse oximetry, electrocardiography and non-invasive blood pressure, was established. Anaesthesia was induced and maintained according to a uniform protocol: pre-oxygenation with 100% oxygen for three minutes, followed by intravenous fentanyl (2 mcg/kg), propofol (2 mg/kg) and suxamethonium (2 mg/kg) to facilitate intubation. Maintenance consisted of 0.6–1% isoflurane in a 1:1 nitrous oxide-oxygen mixture with mechanical ventilation, supplemented with vecuronium and intraoperative paracetamol. At completion of surgery, neuromuscular blockade was reversed with neostigmine and atropine and ondansetron was administered for prophylaxis against postoperative nausea and vomiting. Heart rate, systolic blood pressure, diastolic blood pressure and mean arterial pressure were recorded at baseline (from the pre-anaesthetic assessment), before induction, immediately before extubation and immediately, 5, 10 and 15 minutes after extubation. Based on intraoperative deviation from baseline following induction, patients whose blood pressure remained within 20% of baseline were classified as normotensive (Group N), those exceeding 20% above baseline as hypertensive (Group P) and those falling more than 20% below baseline as hypotensive (Group H). Hypotension was managed with intravenous ephedrine and hypertension with intravenous labetalol or nitroglycerine, according to standard protocol and the frequency of such interventions was recorded as the requirement for anaesthetic modulation. Early recovery was assessed using the Modified Aldrete Scoring System immediately after extubation, before leaving the operating theatre, on arrival in the post-anaesthesia care unit and at 10, 20 and 30 minutes thereafter. Patients were observed for adverse events for six hours postoperatively. All data were obtained from patient records and structured interviews conducted at the pre-anaesthetic checkup, ensuring uniform and reproducible data capture across all participants.

Ethical Consideration

The study protocol was reviewed and approved by the Institutional Review Board of Bangladesh Medical University prior to commencement. The purpose, procedures, potential risks and anticipated benefits of the study were explained to each patient in easily understandable language before written informed consent was obtained. Participants were assured of their unconditional right to withdraw at any stage without any effect on their ongoing clinical care and all data were coded, stored securely and used solely for the purposes of this research to preserve confidentiality and anonymity.

Statistical Analysis

All collected data were compiled into a master chart and analyzed using the Statistical Package for Social Sciences (SPSS), version 26.0 for Windows. Qualitative variables were expressed as frequencies and percentages, while quantitative variables were expressed as mean ± standard deviation. Comparisons of categorical variables between groups were performed using the chi-square test and comparisons of continuous variables across the three groups were performed using one-way analysis of variance (ANOVA). A p-value of less than 0.05 was considered statistically significant throughout.

RESULTS

Sixty diagnosed hypertensive patients undergoing elective surgery under general anaesthesia were enrolled and analyzed. Following induction, patients were allocated to three groups according to intraoperative blood pressure behaviour: normotensive (Group N, n = 32), hypotensive (Group H, n = 12) and hypertensive (Group P, n = 16).

Table I presents the baseline demographic and clinical characteristics of the study population. The age distribution of 60 patients across different groups, with a mean age of 50.3 ± 7.5 years. The weight distribution of 60 patients, with a mean weight of 56.7 ± 5.4 kg. Among the study population, 62% of the participants were male, while 38% were female. The majority (71.7%) were classified as ASA Class II, indicating the presence of mild systemic disease. The remaining 28.3% were categorized as ASA Class III, representing patients with severe systemic disease.

Table I
Baseline demographic and clinical characteristics of the study population (*n* = 60).

Characteristic	Value
Age, years (mean ± SD)	50.3 ± 7.5
Weight, kg (mean ± SD)	56.7 ± 5.4
Sex – Male	37 (61.7%)
Sex – Female	23 (38.3%)
ASA Class II	43 (71.7%)
ASA Class III	17 (28.3%)

Values are expressed as mean ± SD or frequency (percentage). ASA, American Society of Anesthesiologists physical status classification.

Table II presents the distribution of 60 patients according to their blood pressure status during the intraoperative period. The majority (53.3%) were normotensive (Group N), comprising 32 patients. A smaller portion (20%) was classified as hypotensive (Group H), consisting of 12 patients. The remaining 26.7% were classified as hypertensive (Group P), including 16 patients.

Table II
Distribution of patients according to intraoperative blood pressure status (*n* = 60).

Blood pressure status	Group	Frequency (n)	Percentage (%)
Normotensive	Group N	32	53.3
Hypotensive	Group H	12	20.0
Hypertensive	Group P	16	26.7

Group classification was based on ±20% deviation of intraoperative blood pressure from the individual baseline value recorded at the pre-anaesthetic assessment.

Table III compares the mean systolic blood pressure (SBP) among normotensive (Group N), hypotensive (Group H) and hypertensive (Group P) patients at different time intervals. SBP at baseline and before induction showed no statistically significant differences among the groups (P>0.05). However, before and after extubation, Groups N and P had higher mean SBP compared to Group H, which was statistically significant (P<0.05).

Table III
Comparison of systolic blood pressure (mmHg) among the three groups at different time intervals.

Interval	Group N (n=32)	Group H (n=12)	Group P (n=16)	p value
Baseline	137.4±5.9	138.7±6.4	141.2±7.8	0.177
Before induction	141.1±5.6	142.5±6.8	144.9±7.6	0.156
Just before extubation	148.2±7.3	105.6±6.1	175.8±10.8	0.001*
Just after extubation	156.1±7.4	113.6±6.4	183.8±10.7	0.001*
5 min after extubation	151.2±7.9	109.1±5.1	178.1±10.6	0.001*
10 min after extubation	143.4±7.1	112.9±3.6	170.4±10.5	0.001*
15 min after extubation	138.2±6.5	117.5±4.4	165.8±10.6	0.001*

*Values are expressed as mean ± SD. p determined by one-way ANOVA. *statistically significant (p < 0.05).*

In *Table IV*, the comparison of mean diastolic blood pressure (DBP) at the specified time points among the groups showed no statistically significant differences at baseline and before induction (P > 0.05). However, during both the pre-extubation and post-extubation periods, mean DBP values were significantly higher in Groups N and P compared to Group H (P < 0.05).

Table IV
Comparison of diastolic blood pressure (mmHg) among the three groups at different time intervals.

Interval	Group N (n=32)	Group H (n=12)	Group P (n=16)	p value
Baseline	87.5±5.5	88.6±5.2	90.1±6.1	0.323
Before induction	90.7±5.6	92.1±5.9	93.6±6.7	0.257
Just before extubation	100.7±7.8	65.6±7.1	118.5±10.2	0.001*
Just after extubation	105.4±7.3	70.5±7.8	123.5±12.8	0.001*
5 min after extubation	100.2±7.7	65.8±7.7	118.2±9.6	0.001*
10 min after extubation	95.1±6.8	68.2±6.8	113.5±8.3	0.001*
15 min after extubation	90.6±6.2	72.5±5.7	108.6±8.1	0.001*

*Values are expressed as mean ± SD. p determined by one-way ANOVA. *Statistically significant (p < 0.05).*

Table V presents a comparison of heart rates among normotensive (Group N), hypotensive (Group H) and hypertensive (Group P) patients at various time intervals. No statistically significant differences were observed, as P > 0.05.

Table V
Comparison of heart rate (beats/min) among the three groups at different time intervals.

Interval	Group N (n=32)	Group H (n=12)	Group P (n=16)	p value
Baseline	81.3±3.6	79.9±5.1	81.2±3.2	0.566
Before induction	78.2±4.0	76.6±4.7	79.2±3.4	0.243
Just before extubation	75.1±5.2	73.8±5.7	77.3±4.8	0.184
Just after extubation	74.4±8.6	74.1±11.3	77.3±6.7	0.541
5 min after extubation	73.6±8.2	68.8±10.1	73.7±11.5	0.302
10 min after extubation	73.2±8.2	74.6±7.2	77.3±6.6	0.134
15 min after extubation	72.9±6.5	74.8±7.8	77.2±7.6	0.146

Values are expressed as mean ± SD. p determined by one-way ANOVA. No between-group difference reached statistical significance.

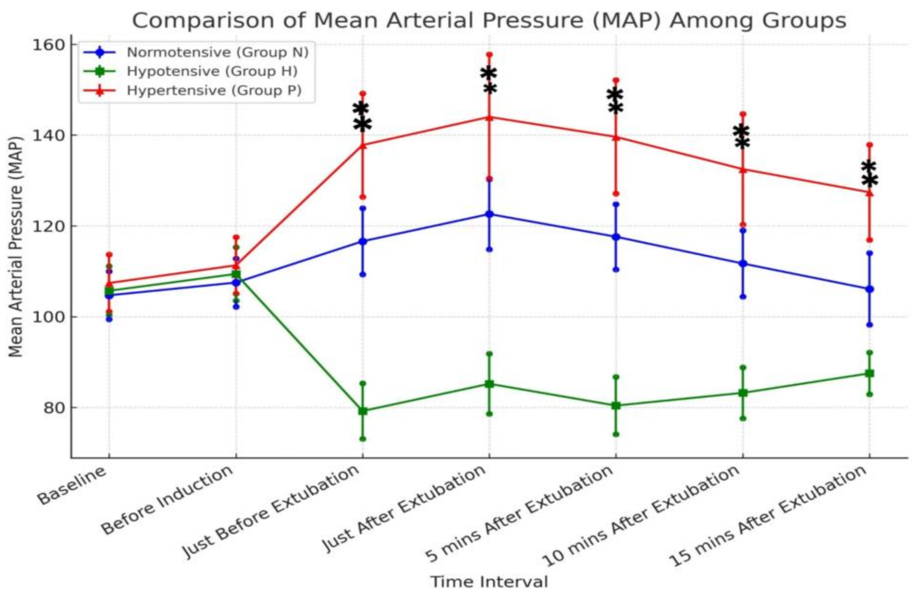
On comparing the Modified Aldrete Score (*Table VI*) among the groups following extubation, before leaving the OT, upon arrival at the PACU and at 10, 20 and 30 minutes after extubation, group N had significantly higher scores compared to group H and group P ($P < 0.05$). Extubation time was longer in Group H and Group P compared to Group N, which is statistically significant ($P < 0.05$).

Table VI
Comparison of extubation time and Modified Aldrete Score among the three groups.

Variable	Group N (n=32)	Group H (n=12)	Group P (n=16)	p value
Extubation time (minutes)	3.5±0.4	4.7±0.5	4.8±0.8	0.001*
Modified Aldrete Score – after extubation	8.9±0.67	7.8±0.83	7.6±0.70	0.001*
Modified Aldrete Score – before leaving OT	8.9±0.63	8.3±0.49	8.0±0.73	0.001*
Modified Aldrete Score – on arrival to PACU	9.1±0.58	8.5±0.42	8.3±0.50	0.001*
Modified Aldrete Score – 10 min after extubation	9.0±0.47	8.6±0.61	8.5±0.54	0.001*
Modified Aldrete Score – 20 min after extubation	9.1±0.50	9.0±0.40	8.8±0.46	0.001*
Modified Aldrete Score – 30 min after extubation	9.2±0.48	9.1±0.52	8.9±0.58	0.001*

*Values are expressed as mean ± SD. p determined by one-way ANOVA. OT, operating theatre; PACU, post-anaesthesia care unit. *Statistically significant (p < 0.05).*

Figure 1 shows a significant difference in MAP among the groups during the pre-extubation and post-extubation periods ($P < 0.05$), which is statistically significant. However, baseline and pre-induction MAP values showed no statistically significant differences ($P > 0.05$).



Significant p-values (p < 0.05, p < 0.001, p < 0.0001) are marked consecutively with asterisks (, **, ***).*

Figure 1 Flowchart comparing Mean Arterial Pressure (MAP) among the groups over different time intervals.

DISCUSSION

The present cohort of diagnosed hypertensive patients had a mean age of 50.3 ± 7.5 years, a distribution broadly consistent with the population described by Shailaja and Srikantu [12], although Abidin et al. [13] examined a comparatively younger group, with a mean age of 38.74 ± 4.36 years, drawn specifically from patients with controlled hypertension. The present sample was also more heterogeneous in physical status, comprising 71.7% ASA Class II and 28.3% ASA Class III patients, in contrast with the entirely ASA Class II population reported by Abidin et al. [13], reflecting inclusion of a somewhat higher-risk surgical population in the present analysis. Classification of patients by intraoperative blood pressure behaviour showed that 53.3% remained normotensive, 20.0% became hypotensive and 26.7% became hypertensive following induction. Crowther et al. [14] reported a broadly comparable pattern in a hypertensive surgical cohort, with intraoperative hypertension occurring in 47.8% of patients and hypotension, defined as a mean arterial pressure below 55 mmHg sustained for at least one minute, occurring in 18.2%. Tang et al. [15], studying elective laparoscopic surgery, similarly described acute intraoperative hypertension in 46.6% of patients, with a substantial proportion of hypertensive episodes clustering around induction and extubation, a distribution that mirrors the concentration of blood pressure elevation observed around the extubation window in the present study.

Systolic and diastolic pressures, together with the mean arterial pressure derived from them, diverged sharply between groups once the pre-extubation period was reached. Whereas baseline and pre-induction values were statistically indistinguishable across the normotensive, hypotensive and hypertensive groups, systolic pressure immediately after extubation reached 156.1 ± 7.4 mmHg in the normotensive group, fell to 113.6 ± 6.4 mmHg in the hypotensive group and rose to 183.8 ± 10.7 mmHg in the hypertensive group, a divergence that persisted throughout the fifteen-minute observation window ($p = 0.001$ at every post-extubation interval). Diastolic pressure followed an almost identical pattern and the derived mean arterial pressure trend confirmed a pronounced peak immediately after tube removal in the hypertensive group before a gradual return toward baseline over the subsequent fifteen minutes. This behaviour is consistent with the chronic hypovolaemia and heightened vascular resistance that characterize hypertensive physiology, a state that predisposes to disproportionate pressor responses even when baseline readings appear well controlled [16]. Impaired cerebral autoregulation in chronically hypertensive patients further complicates the interpretation of any fixed percentage deviation from baseline, since the tolerable range of blood pressure fluctuation before cerebral perfusion is compromised differs meaningfully between individuals [17].

The sympathetic surge that accompanies airway manipulation at extubation has previously been shown to drive exaggerated pressor responses in hypertensive patients [8] and the present findings extend this observation by demonstrating that the divergence between groups was already evident in the moments immediately preceding tube removal rather than emerging only afterward, suggesting that the pre-extubation interval itself carries useful predictive information. The physiological drivers of these bidirectional swings are well described: intraoperative blood pressure may fall owing to volatile anaesthetic-induced sympathetic suppression and impaired baroreceptor reflex activity [18], while it may rise in response to surgical stimulation, excessive fluid administration or inadequate depth of anaesthesia, particularly in patients whose preoperative hypertension is incompletely controlled [19].

Recovery, assessed using the Modified Aldrete Scoring System, tracked closely with intraoperative blood pressure status. Immediately after extubation, normotensive patients achieved a mean score of 8.9 ± 0.67, compared with 7.8 ± 0.83 in the hypotensive group and 7.6 ± 0.70 in the hypertensive group, a difference that remained statistically significant at every subsequent post-anaesthesia care unit time point up to thirty minutes. Extubation time was correspondingly prolonged in both the hypotensive (4.7 ± 0.5 minutes) and hypertensive (4.8 ± 0.8 minutes) groups relative to the normotensive group (3.5 ± 0.4 minutes, $p = 0.001$). Banerjee et al. [20] and Yamaguchi et al. [21] have both underscored the value of the Modified Aldrete Score as a sensitive marker of early postoperative recovery and Valasareddy et al. [22] similarly relied on this instrument to characterize recovery profile following general anaesthesia, supporting its use in the present analysis to link intraoperative haemodynamic behaviour with functional recovery outcome. Taken together, these findings indicate that blood pressure instability recorded in the pre-extubation window is not an isolated intraoperative phenomenon but a meaningful predictor of the pace and quality of early recovery, reinforcing the case for closer haemodynamic surveillance and more individualized extubation planning in hypertensive surgical patients.

LIMITATIONS

This single-center observational study has a modest sample size and cannot establish causation. A key limitation is that the specific number, type, and dosage of antihypertensive medications were not documented, although these factors significantly influence intraoperative blood pressure control. Future multicenter trials with larger cohorts and detailed medication records are recommended, along with interventional studies to test personalized extubation protocols based on pre-extubation blood pressure trends to optimize recovery in hypertensive patients.

CONCLUSION

Hypertensive patients undergoing general anaesthesia exhibit pronounced blood pressure fluctuations that become clinically apparent from the pre-extubation period onward, well before the endotracheal tube is removed. Both intraoperative hypertension and hypotension were associated with prolonged extubation time and lower recovery scores on the Modified Aldrete Scale compared with normotensive patients, indicating that pre-extubation blood pressure behaviour carries meaningful prognostic information regarding early recovery quality. These findings support closer haemodynamic surveillance during the pre-extubation window and suggest that targeted intervention at this stage, rather than only after extubation, may help attenuate adverse recovery trajectories in hypertensive surgical patients.

ACKNOWLEDGMENT

I would like to express my sincere gratitude for the invaluable support and cooperation provided by the staff, participants and my co-authors/colleagues who contributed to this study.

CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

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