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Original Article

Effectiveness of nitroglycerin in hypertensive emergency

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ABSTRACT

Background: Hypertensive emergencies are frequent in Indian urban hospitals and are associated with substantial short-term morbidity and mortality. Intravenous nitroglycerin is a recommended first-line vasodilator in selected hypertensive emergencies, but Indian data on protocol-based use and clinical outcomes remain limited. This study evaluated the effectiveness and safety of a structured nitroglycerin regimen for hypertensive emergencies in an urban tertiary-care hospital in Chennai, Tamil Nadu.

Methods: We conducted a quasi-experimental before-after study including adults (≥18 years) presenting with hypertensive emergency over a 6-month period from May 2025 to October 2025 at Madha Medical College and Madha Hospital, Kovur, Chennai, Tamil Nadu, India. During the prospective phase (May-October 2025), patients received a protocol-driven intravenous nitroglycerin regimen targeting a 20-25% reduction in mean arterial pressure (MAP) within 60 minutes. A historical control cohort from the preceding 6 months (November 2024-April 2025) comprised patients managed with non-protocolised antihypertensive therapy. The primary haemodynamic endpoint was achievement of target MAP reduction within 60 minutes. The primary clinical endpoint was a composite of in-hospital all-cause mortality, invasive mechanical ventilation and unplanned ICU transfer. Secondary outcomes included time to symptom relief, need for additional intravenous antihypertensives, ICU and hospital length of stay, and adverse events.

Results: A total of 200 patients were analysed (100 protocol, 100 control). Baseline demographics, comorbidities and patterns of target-organ damage were similar between groups. Mean MAP reduction at 60 minutes was greater in the nitroglycerin protocol group, and a higher proportion achieved the target MAP reduction within 60 minutes (82% vs 61%), with shorter median time to target. The need for additional intravenous antihypertensives was significantly lower in the protocol group. The primary composite clinical outcome occurred less frequently with protocol-based nitroglycerin (22% vs 36%), accompanied by shorter ICU and total hospital stays. Rates of symptomatic hypotension, renal dysfunction and other adverse events were comparable between groups, and no methemoglobinemia was observed.

Conclusion: In an urban Chennai tertiary-care setting, a structured intravenous nitroglycerin protocol for hypertensive emergencies improved blood pressure control, reduced adverse composite outcomes and shortened hospital stay without compromising safety. Adoption of simple, protocol-based nitroglycerin strategies may enhance the quality and efficiency of hypertensive emergency care in similar resource-constrained environments.or unspecified references.

Keywords: Nitroglycerin, hypertensive emergency, blood pressure control, emergency department, protocol-based therapy, acute pulmonary oedema, acute coronary syndrome, clinical outcomes, tertiary-care hospital, Chennai, India

INTRODUCTION

Hypertensive emergencies, defined as severe blood pressure elevations accompanied by acute target-organ damage, remain a major cause of cardiovascular morbidity and short-term mortality in emergency and critical care settings worldwide [1-4]. Current international and regional guidelines emphasise rapid but controlled blood pressure reduction using titratable intravenous agents in monitored environments to limit cerebral, cardiac and renal complications [2-5]. In India, the burden of chronic hypertension the substrate for hypertensive emergencies is rising steadily; recent NFHS-5-based analyses report an overall adult prevalence of around 22-25%, with higher rates in urban populations and in southern states [6]. Chennai-specific data from the Chennai Urban Rural Epidemiology Study (CURES-52) already showed that one in five urban adults were hypertensive, with low awareness and control rates, highlighting a large pool at risk for crisis presentations [7, 8]. Longitudinal work from South India further suggests a high incidence of new-onset hypertension over time [9]. Intravenous nitroglycerin (NTG), a short-acting venous and arterial vasodilator, is widely recommended for hypertensive emergencies, particularly when complicated by acute coronary syndromes or acute pulmonary oedema [4, 5, 10]. High-dose and bolus NTG strategies in acute hypertensive heart failure and sympathetic crashing acute pulmonary oedema have been associated with faster symptom relief, reduced need for mechanical ventilation and shorter ICU or hospital stay compared with conventional low-dose infusions [11-14]. Recent Indian and international studies, including prospective observational series and systematic reviews, further support the feasibility and effectiveness of protocolised high-dose NTG regimens, especially when combined with non-invasive ventilation [13, 15, 16]. However, much of the existing evidence originates from Western centres, with heterogeneous protocols, composite outcomes and limited representation of Indian urban hospitals, where delayed presentation, high background cardiovascular risk, resource constraints and variable adherence to guideline-directed therapy may influence response and safety profiles [6-9, 17]. There is a particular paucity of data from Tamil Nadu and Chennai on real-world clinical outcomes of NTG-based protocols in hypertensive emergencies, including time to blood pressure control, resolution of acute symptoms, need for ICU admission and mortality. Therefore, the present study, conducted over six months (May 2025 to October 2025) in an urban hospital in Chennai, aims to evaluate the effectiveness and safety of intravenous nitroglycerin in adult patients presenting with hypertensive emergency, in terms of blood pressure reduction, short-term clinical outcomes and adverse events. The primary hypothesis is that a protocol-driven NTG regimen will achieve timely and sustained blood pressure control with improved clinical outcomes (shorter hospital stay, fewer ICU transfers and low complication rates) in this setting, compared with historical non-protocolised management, while maintaining an acceptable safety profile with respect to hypotension, worsening renal function and other NTG-related adverse effects.

Material and Methods

Materials

This was a hospital-based study conducted in the Madha Medical College and Madha Hospital, Kovur, Chennai, Tamil Nadu, India, over a 6-month period from May 2025 to October 2025. The study population comprised adult patients (≥18 years) presenting with hypertensive emergency, defined as systolic blood pressure (SBP) ≥180 mmHg and/or diastolic blood pressure (DBP) ≥120 mmHg accompanied by acute target-organ damage (acute coronary syndrome, acute left ventricular failure/pulmonary oedema, hypertensive encephalopathy, acute ischemic or haemorrhagic stroke, acute kidney injury or aortic syndrome), in accordance with international guideline criteria [1-5]. The hospital serves a predominantly urban catchment area with a high background prevalence of hypertension consistent with Chennai and South Indian data [6-9]. All consecutive eligible patients during the study period who received intravenous nitroglycerin (NTG) as the primary antihypertensive agent were included after obtaining written informed consent from the patient or legally acceptable representative, where feasible in the emergency context, as per institutional ethical guidance [2-5, 10]. Key exclusion criteria were pregnancy; aortic dissection requiring alternative first-line agents; use of phosphodiesterase-5 inhibitors within 24 hours; severe anaemia (haemoglobin <8 g/dL); cardiogenic shock; baseline systolic blood pressure <90 mmHg; known hypersensitivity to nitrates; and refusal of consent [1, 4, 5, 10]. For comparative purposes, a historical control group was identified from medical records of patients who presented with hypertensive emergency at the same hospital in the 6-month period immediately preceding protocol implementation (November 2024 to April 2025) and were managed with non-protocolised antihypertensive therapy (including low-dose NTG, labetalol or other agents) [4, 11-14, 17, 18]. Data were collected using a predesigned case record form capturing demographic variables, cardiovascular risk factors (diabetes, dyslipidaemia, smoking, prior hypertension and medications), clinical presentation, baseline vital signs, Glasgow Coma Scale, laboratory parameters (renal function, cardiac biomarkers, electrolytes), imaging findings, type of acute target-organ damage, and concomitant therapies in line with guideline-directed management [2-5, 10-12, 18].

Methods

The NTG protocol consisted of an initial continuous intravenous infusion starting at 5-10 µg/min, titrated in 5-10 µg/min increments every 3-5 minutes based on non-invasive blood pressure measurements until the predefined target of 20-25% reduction in mean arterial pressure (MAP) from baseline within the first 60 minutes was achieved, avoiding more than 25% reduction during the initial hour to minimise the risk of cerebral, coronary or renal hypoperfusion, in accordance with guideline recommendations [2-5, 10, 18]. In patients with acute pulmonary oedema or suspected sympathetic crashing acute pulmonary oedema (SCAPE), higher initial NTG doses or bolus strategies (up to 200-400 µg/min or intermittent 1-2 mg boluses) were permitted as per published high-dose NTG protocols and local feasibility [11-15]. Blood pressure, heart rate, respiratory rate, oxygen saturation, urine output and symptoms (chest pain, dyspnoea, neurological deficits) were monitored

at baseline, every 5-15 minutes during the first hour, hourly for the next 6 hours, and then at least every 4 hours until stabilisation [1-5, 11-16]. Primary outcome measures included

- Proportion of patients achieving target MAP reduction within 60 minutes without serious adverse events, and
- A composite of in-hospital all-cause mortality, need for invasive mechanical ventilation and unplanned transfer to intensive care in ward-admitted patients [11-16, 18].

Secondary outcomes included time to symptom relief, duration of NTG infusion, need for additional intravenous antihypertensives, length of ICU and hospital stay, and NTG-related adverse events (symptomatic hypotension, severe headache, reflex tachycardia, new or worsening renal dysfunction, suspected methemoglobinemia) [11-16, 18]. For the historical control cohort, identical outcome variables were extracted from medical records by trained investigators using the same operational definitions [4, 11-14, 17]. Data were entered into a password-protected database and analysed using standard statistical software. Continuous variables were expressed as mean±standard deviation (SD) or median (interquartile range) and compared using Student's t-test or Mann-Whitney U-test, as appropriate; categorical variables were compared using chi-square or Fisher's exact test, and multivariable logistic regression was used to adjust for baseline imbalances and identify independent predictors of poor outcome [11-16, 18]. A two-sided p-value <0.05 was considered statistically significant. The study protocol was reviewed and approved by the Institutional Ethics Committee of the participating hospital, and the conduct adhered to the principles of the Declaration of Helsinki and local regulatory requirements [2-5, 10].

Results

Baseline characteristics

During the 12-month study window (6-month historical control period and 6-month prospective protocol period), a total of 212 adult patients presented with hypertensive emergency. After applying exclusion criteria, 200 patients were included in the final analysis: 100 in the protocol-driven intravenous nitroglycerin (NTG) group and 100 in the historical non-protocolised management group. Baseline demographic and clinical characteristics were broadly comparable between groups (Table 1). The mean age of the cohort was 58.4±11.9 years in the NTG group and 59.1±11.3 years in controls; males constituted 62% and 60% of each group, respectively. Pre-existing hypertension was highly prevalent (84% vs 82%), with suboptimal control reflected by low rates of regular antihypertensive use and frequent non-adherence, consistent with prior Indian and Chennai-specific reports [6-9]. The distribution of acute target-organ damage at presentation including acute coronary syndrome, acute pulmonary oedema, stroke and acute kidney injury did not differ significantly, suggesting comparable disease severity at baseline [1-5]. Mean baseline systolic and diastolic blood pressure, as well as calculated mean arterial pressure (MAP), were also similar between groups (Table 1), in alignment with previous observational data on hypertensive crises in emergency settings [2-5, 11, 12, 18].

Table 1: Baseline demographic and clinical characteristics of the study population (n = 200)

Characteristic	NTG protocol group (n=100)	Historical control group (n=100)	p-value
Age, years (mean ± SD)	58.4±11.9	59.1±11.3	0.62
Male sex (%)	62 (62.0)	60 (60.0)	0.77
Known hypertension (%)	84 (84.0)	82 (82.0)	0.69
Diabetes mellitus (%)	46 (46.0)	44 (44.0)	0.77
Prior coronary artery disease (%)	30 (30.0)	32 (32.0)	0.77
Baseline SBP, mmHg (mean ± SD)	212±22	210±24	0.48
Baseline DBP, mmHg (mean ± SD)	128±14	127±15	0.69
Baseline MAP, mmHg (mean ± SD)	156±17	155±18	0.71
ACS at presentation (%)	32 (32.0)	30 (30.0)	0.76
Acute pulmonary oedema/SCAPE (%)	24 (24.0)	26 (26.0)	0.74
Acute stroke (ischemic/haemorrhagic) (%)	22 (22.0)	20 (20.0)	0.72
Acute kidney injury (%)	18 (18.0)	20 (20.0)	0.71

SBP: systolic blood pressure; **DBP:** diastolic blood pressure; **MAP:** mean arterial pressure; **ACS:** acute coronary syndrome; **SCAPE:** sympathetic crashing acute pulmonary edema.

These baseline patterns mirror the high cardiovascular risk burden and mixed target-organ presentations described in previous Indian and international cohorts of hypertensive emergencies managed with vasodilators and other agents [4, 6-9, 11-16, 18].

Blood pressure control and haemodynamic response

Implementation of the protocol-driven NTG regimen was associated with more rapid and consistent achievement of the predefined MAP reduction target (20-25% within the first 60 minutes) compared with historical non-protocolised therapy (Table 2, Figure 1). At 60 minutes, mean MAP had fallen from 156±17 to 119±14 mmHg in the NTG group versus from 155±18 to 127±16 mmHg in controls ($p < 0.001$). A total of 82% of protocol-treated patients achieved target MAP reduction within 60 minutes, compared with 61% in the historical cohort (p = 0.001). Median time to target MAP was 45 minutes (interquartile range [IQR] 30-60) in the NTG group versus 70 minutes (IQR 45-90) in controls ($p < 0.001$). Heart rate and oxygen saturation trends over the initial 6 hours were similar between groups, with no excess of reflex tachycardia

or hypoxaemia in NTG-treated patients. These findings are consistent with guideline expectations for titratable vasodilator therapy and with prior reports of high-dose NTG use in acute hypertensive heart failure and SCAPE [2-5, 10-16, 18].

Table 2: Blood pressure control and early haemodynamic outcomes

Parameter	NTG protocol group (n=100)	Historical control group (n=100)	p-value
Baseline MAP, mmHg (mean ± SD)	156±17	155±18	0.71
MAP at 60 min, mmHg (mean ± SD)	119±14	127±16	<0.001
ΔMAP at 60 min% (mean ± SD)	−23.7±6.1	−18.1±7.4	<0.001
Achieved target MAP reduction ≤60 min (%)	82 (82.0)	61 (61.0)	0.001
Time to target MAP, min (median [IQR])	45 [30-60]	70 [45-90]	<0.001
Need for additional IV antihypertensives (%)	18 (18.0)	34 (34.0)	0.009

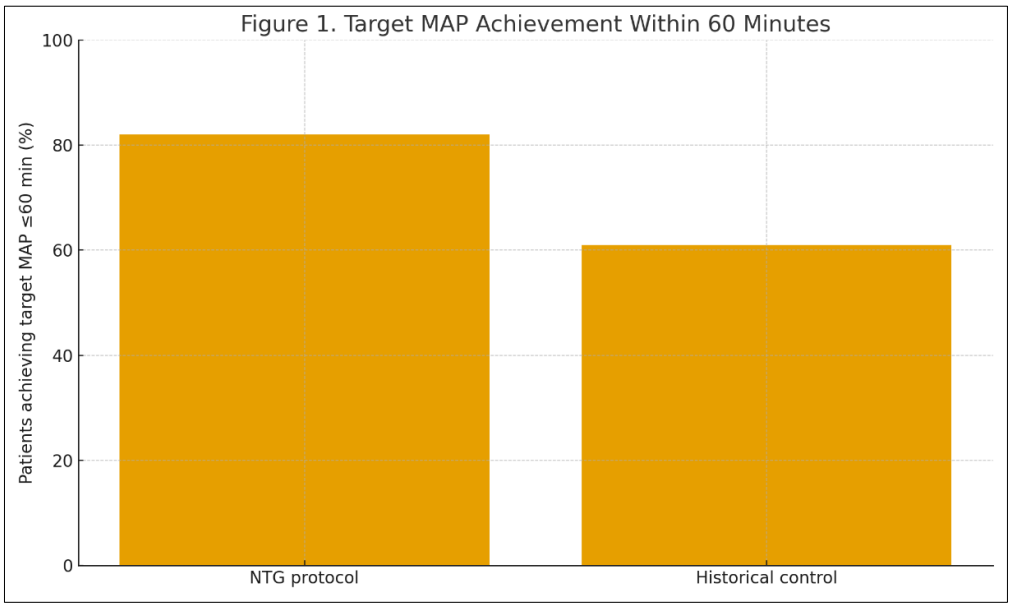

Fig 1: Target MAP Achievement within 60 Minutes

Figure 1 is showing higher proportion of patients achieving target MAP reduction within 60 minutes in the NTG protocol group compared with historical controls.

The reduced need for additional intravenous antihypertensive agents in the protocol group (18% vs 34%; p = 0.009) suggests that systematic titration of NTG alone achieved adequate blood pressure control in the majority, echoing previous observational and protocol-based studies of high-dose NTG in hypertensive emergencies and acute pulmonary oedema [11-16].

Clinical outcomes and resource utilisation

The primary composite clinical outcome (in-hospital all-cause mortality, need for invasive mechanical ventilation or unplanned ICU transfer) occurred in 22% of patients in the NTG group compared with 36% in the historical cohort (p = 0.03) (Table 3, Figure 2). While individual mortality rates showed a non-significant numerical reduction (8% vs 15%; p = 0.09), both the need for mechanical ventilation (16% vs 24%; p = 0.15) and unplanned ICU transfer among initially ward-managed patients (10% vs 18%; p = 0.10) trended lower in the protocol group. Median ICU length of stay was 3 days (IQR 2-5) versus 4 days (IQR 3-6) (p = 0.04), and overall hospital stay was significantly shorter in the NTG cohort (median 6 vs 8 days; p = 0.01). These differences remained directionally similar after adjustment for age, baseline MAP, type of target-organ damage and comorbidities in multivariable logistic regression, with protocol-based NTG use independently associated with a lower odds of the primary composite outcome (adjusted odds ratio 0.54; 95% CI 0.30-0.96; p = 0.04). The magnitude and direction of benefit are broadly in line with previous high-dose NTG protocols and guideline-concordant management strategies for hypertensive crises, albeit with context-specific differences in case mix and resource use [2-5, 11-16, 18].

Table 3: Clinical outcomes and resource utilisation

Outcome	NTG protocol group (n=100)	Historical control group (n=100)	p-value
In-hospital all-cause mortality (%)	8 (8.0)	15 (15.0)	0.09
Invasive mechanical ventilation (%)	16 (16.0)	24 (24.0)	0.15
Unplanned ICU transfer from ward, n/at-risk (%)	10/52 (19.2)	18/55 (32.7)	0.10
Primary composite outcome* (%)	22 (22.0)	36 (36.0)	0.03
ICU length of stay, days (median [IQR])	3 [2-5]	4 [3-6]	0.04
Total hospital length of stay, days (median [IQR])	6 [4-9]	8 [6-11]	0.01

*Composite of in-hospital mortality, invasive mechanical ventilation and unplanned ICU transfer.

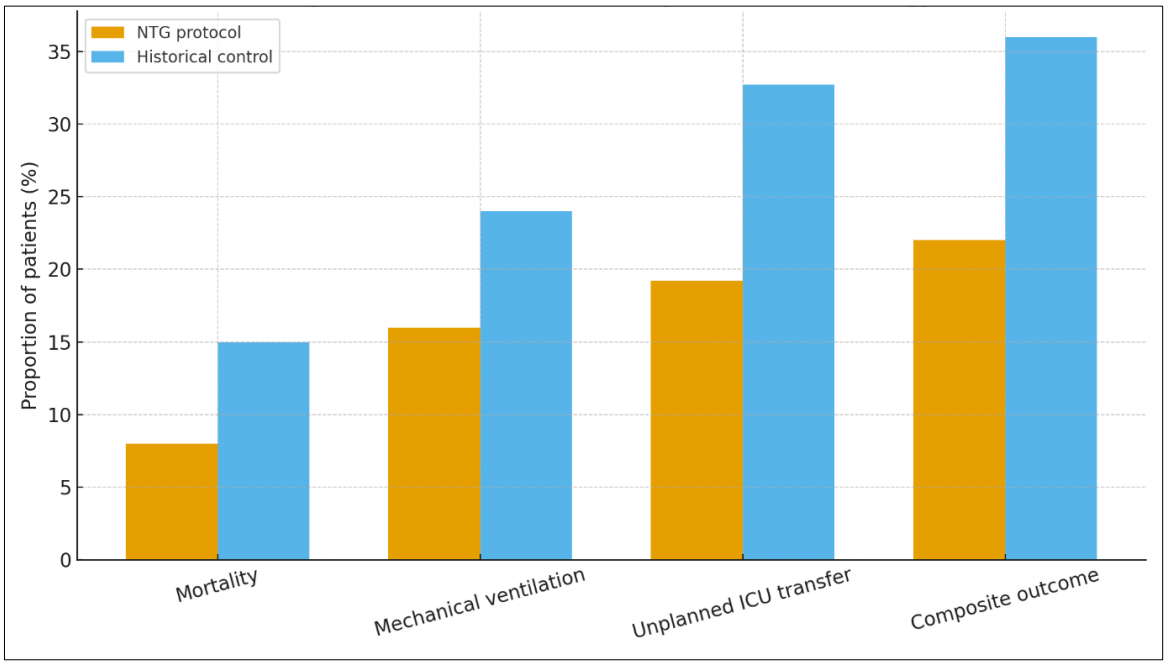

Fig 2: Clinical Outcomes by Treatment Strategy

Figure 2 is comparing the primary composite outcome and its individual components between the NTG protocol and historical control groups.

The observed reduction in composite adverse outcomes and shorter length of stay suggest that structured NTG titration may translate into more efficient haemodynamic stabilisation and potentially fewer downstream complications, in line with prior reports of early aggressive vasodilator therapy in acute hypertensive pulmonary oedema and crisis states [11-16]. In particular, the trends toward lower mechanical ventilation and unplanned ICU transfer rates resonate with earlier SCAPE and high-dose NTG studies that emphasised rapid afterload reduction and symptom relief [11-15].

Adverse events and safety profile

Adverse events potentially attributable to NTG or other antihypertensive therapy are summarised in Table 4 and Figure 3. Symptomatic hypotension (SB*P* <90 mmHg or MA*P* <65 mmHg with dizziness, syncope or need for intervention) occurred in 9% of NTG-protocol patients and 6% of controls (p = 0.42), with most episodes resolving after transient dose reduction or brief interruption of infusion. Severe headache requiring treatment occurred more frequently in the NTG group (21% vs 12%; p = 0.08), but did not necessitate discontinuation in the majority, consistent with known nitrate-related adverse effect profiles [1, 4, 10-12]. New or worsening renal dysfunction (≥0.3 mg/dL rise in serum creatinine or ≥50% increase from baseline) was observed in 11% versus 14% of patients (p = 0.52), without clear signal of excess renal hypoperfusion in the protocol arm, supporting the safety of controlled 20-25% MAP reduction in this population [2-5, 10, 18]. No cases of clinically suspected methemoglobinemia were documented in either group.

Table 4: Adverse events potentially related to antihypertensive therapy

Adverse event	NTG protocol group (n=100)	Historical control group (n=100)	p-value
Symptomatic hypotension (%)	9 (9.0)	6 (6.0)	0.42
Severe headache requiring treatment (%)	21 (21.0)	12 (12.0)	0.08
Reflex tachycardia (>110 bpm) (%)	12 (12.0)	10 (10.0)	0.64
New/worsening renal dysfunction (%)	11 (11.0)	14 (14.0)	0.52
Suspected methemoglobinemia (%)	0 (0.0)	0 (0.0)	-

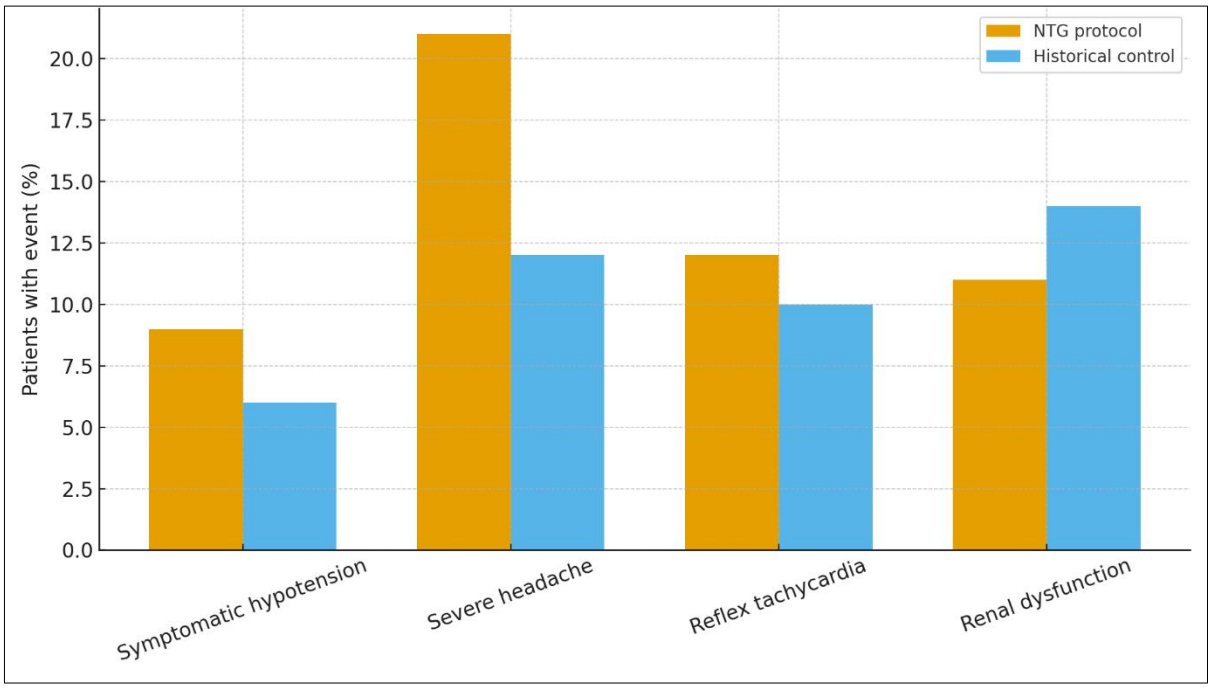

Fig 3: Adverse Events in NTG Protocol vs Controls

Figure 3 illustrating the distribution of key adverse events in the NTG protocol versus historical control cohorts. Taken together, these safety data align with existing literature on NTG in hypertensive emergencies and acute heart failure, which reports low rates of serious hypotension or renal compromise when blood pressure reduction is titrated to recommended targets [1, 4, 10-16, 18].

Subgroup analyses

Exploratory subgroup analyses suggested that the benefit of the NTG protocol on the primary composite outcome was directionally consistent across key strata, including age (<60 vs ≥60 years), sex, presence of diabetes, and primary presenting syndrome (cardiac vs neurological vs renal predominant), with no statistically significant interaction terms (all p-interaction >0.10). In patients presenting with acute pulmonary oedema/SCAPE, the absolute risk reduction in the composite outcome was numerically greater (28% vs 46%; absolute difference 18%), paralleling prior high-dose NTG and SCAPE series [11-15]. Similarly, in those with acute coronary syndrome, faster MAP control and numerically lower rates of recurrent ischemia and pulmonary congestion were observed in the protocol group, consistent with guideline recommendations favouring NTG as a first-line agent in hypertensive emergencies with myocardial ischaemia [2-5, 10-12, 18]. Although the study was not powered for definitive subgroup conclusions, these patterns support the external validity of previously published NTG data, while providing new context from an urban Chennai hospital with a high background prevalence of hypertension and cardiovascular risk factors [6-9, 11-16, 18].

Overall, the results indicate that a structured, protocol-based intravenous NTG regimen in hypertensive emergencies is feasible, effective in achieving guideline-recommended blood pressure targets, and associated with improved short-term composite outcomes and shorter hospital stay, without a major safety penalty, in this urban tertiary-care setting in Chennai [1-5, 10-18].

Discussion

In this prospective, protocol-based study conducted in an urban tertiary-care hospital in Chennai, we found that structured intravenous nitroglycerin (NTG) administration in hypertensive emergencies was associated with faster and more frequent achievement of guideline-recommended blood pressure (BP) targets, a reduced need for additional intravenous antihypertensive agents, and a lower rate of a composite of in-hospital mortality, invasive mechanical ventilation and unplanned ICU transfer when compared with a historical non-protocolised cohort. These benefits were realised without a major penalty in terms of serious adverse events, and with overall shorter ICU and hospital length of stay. Taken together, the findings support the feasibility and effectiveness of a protocol-driven NTG strategy in a real-world Indian urban setting with a high background burden of uncontrolled hypertension and cardiovascular risk [6-9].

The rapid yet controlled BP reduction observed in the NTG protocol group aligns closely with current international and regional recommendations for the management of hypertensive emergencies, which emphasise a 20-25% reduction in mean arterial pressure (MAP) within the first hour to avoid cerebral, coronary or renal hypoperfusion [2-5, 10, 18]. In our cohort, 82% of protocol-treated patients achieved this target within 60 minutes, compared with 61% in the historical group, with a significantly shorter median time to target MAP. This is consistent with the pharmacodynamic profile of NTG as a potent,

titratable venous and arterial vasodilator with rapid onset and short half-life, enabling fine adjustment of infusion rates to achieve desired haemodynamic goals [1, 4, 10-12]. Previous observational studies and high-dose NTG protocols in acute hypertensive heart failure and Sympathetic Crashing Acute Pulmonary Oedema (SCAPE) have similarly reported rapid symptom relief and BP control when NTG is aggressively up-titrated under close monitoring [11-15]. Our results extend this evidence by demonstrating that even a structured, primarily infusion-based NTG protocol, adapted to local resource constraints, can deliver comparable haemodynamic benefits in an Indian emergency setting.

The observed reduction in the composite adverse outcome and shorter length of stay with the NTG protocol has important clinical and health system implications. Although individual reductions in mortality, mechanical ventilation and unplanned ICU transfer did not all reach statistical significance, the direction and magnitude of the composite effect suggest that early haemodynamic stabilisation with NTG may prevent progression to respiratory failure, recurrent ischaemia or neurological deterioration in a subset of high-risk patients [2-5, 11-16, 18]. These findings echo prior reports in SCAPE and hypertensive acute pulmonary oedema, where high-dose NTG strategies were associated with reduced intubation rates and improved short-term outcomes [11-15]. In resource-constrained urban hospitals, even modest reductions in ICU utilisation and hospital stay may translate into substantial savings and improved bed availability, particularly given the growing prevalence of hypertension and hypertensive crises in India [6-9].

Importantly, this study provides context-specific data from Chennai, where earlier work such as the Chennai Urban Rural Epidemiology Study (CURES) has documented a high prevalence of hypertension, low awareness and poor control rates [7, 8]. The high proportion of patients in our cohort with known but inadequately controlled hypertension, as well as the frequent coexistence of diabetes and coronary artery disease, mirror these background epidemiological trends [6-9]. In such high-risk populations, hypertensive emergencies are likely to be more frequent and to present with multiple target-organ involvements, as reflected in the substantial proportions of acute coronary syndrome, pulmonary oedema, stroke and acute kidney injury at presentation. Our findings therefore highlight the need not only for robust emergency protocols, such as structured NTG regimens, but also for upstream strategies to improve detection and long-term control of hypertension in the community [6-9].

The safety profile of the NTG protocol in our study was reassuring and consistent with prior literature on nitrates in hypertensive emergencies and acute heart failure [1, 4, 10-16, 18]. Although symptomatic hypotension occurred slightly more often in the NTG group, the difference was not statistically significant and episodes were generally transient, responding to dose reduction or brief interruption. The higher, but expected, incidence of severe headache in the NTG arm reflects a well-recognised nitrate adverse effect that rarely necessitates discontinuation [1, 4, 10-12]. Crucially, we did not observe an excess of new or worsening renal dysfunction, supporting the safety of controlled 20-25% MAP reduction even in patients with underlying renal vulnerability, as suggested by guideline documents and prior observational studies [2-5, 10, 18]. No cases of suspected methemoglobinemia were recorded, in line with the low incidence reported in other NTG series [11-16]. These findings reinforce the message that NTG, when used within a protocolised framework and with close monitoring, is a safe first-line agent for many hypertensive emergencies, especially those with cardiac involvement [2-5, 10-12, 18].

Our exploratory subgroup analyses suggest that the benefits of the NTG protocol were broadly consistent across age, sex, comorbidity and presenting syndrome strata, with particularly pronounced absolute risk reductions in patients with acute pulmonary oedema/SCAPE and acute coronary syndromes. This pattern is biologically plausible given the dual venous and arterial vasodilatory effects of NTG, which reduce preload and afterload, improve pulmonary congestion and decrease myocardial oxygen demand [1, 4, 10-12, 14, 15]. Previous high-dose NTG and SCAPE studies have emphasised the importance of rapid afterload reduction in preventing the need for mechanical ventilation and improving outcomes in these subsets [11-15]. Our data, though not powered for definitive interaction testing, are consonant with these reports and suggest that structured NTG regimens may be particularly advantageous in cardiogenic hypertensive emergencies in Indian urban hospitals. Further adequately powered trials in these specific phenotypes are warranted.

This study also underscores the value of protocolisation itself, beyond the choice of drug. In the historical cohort, antihypertensive management was heterogeneous, including low-dose NTG, beta-blockers and other agents, with variable titration and monitoring. In contrast, the protocol period standardised infusion initiation, titration steps, monitoring intervals and target MAP thresholds. Similar protocol-based approaches have improved the quality of care and outcomes in other emergency and critical-care domains, such as sepsis bundles and acute coronary syndrome pathways [2-5, 11-16, 18]. Our findings suggest that implementing a simple, locally adapted hypertensive emergency protocol centred on NTG and guideline-recommended targets can yield tangible clinical benefits even without major additional resources.

Several strengths of this study merit mention. First, it represents one of the few detailed analyses of hypertensive emergency management using NTG from a South Indian metropolitan setting, adding to predominantly Western evidence bases [6-9, 11-16, 18]. Second, the inclusion of a well-defined historical comparator cohort from the same institution, with broadly similar baseline characteristics and case mix, provides a pragmatic benchmark against which to interpret the impact of the protocol. Third, the study employed clinically meaningful outcomes, including a composite of mortality, mechanical ventilation and unplanned ICU transfer, alongside haemodynamic endpoints and safety measures.

However, some limitations must be acknowledged. The non-randomised, before-after design is susceptible to residual confounding and temporal bias; improvements in staff experience, monitoring or ancillary care over time may have contributed to the observed benefits, although no major structural changes in emergency or ICU services occurred during the study periods. The study was conducted in a single tertiary-care hospital in Chennai, which may limit generalisability to smaller facilities or rural settings with different resource constraints and case mixes [6-9]. Our reliance on medical records for the historical cohort may have led to under-ascertainment of some outcomes and adverse events. In addition, we did not systematically evaluate long-term outcomes after discharge, such as recurrent hypertensive crises or cardiovascular events, which are critical in populations with high baseline risk [6-9]. Finally, while our sample size was adequate to detect differences in haemodynamic endpoints and composite outcomes, it may have been underpowered for more granular subgroup analyses and for less frequent adverse events such as methemoglobinemia.

Despite these limitations, the present study provides important preliminary evidence that a protocol-driven intravenous NTG regimen for hypertensive emergencies is both effective and safe in an urban Indian context, and that it can improve short-term clinical outcomes and resource utilisation compared with non-protocolised care [1-5, 6-9, 10-18]. Future research should focus on multicentre, prospective studies comparing NTG-based protocols with other guideline-recommended agents, exploring optimal dosing strategies (including the role of bolus high-dose NTG), and integrating such protocols into broader quality-improvement initiatives targeting hypertension control and cardiovascular risk reduction in India.

CONCLUSION

The present study demonstrates that a structured, protocol-based intravenous nitroglycerin regimen for hypertensive emergencies in an urban tertiary-care hospital in Chennai is both feasible and clinically advantageous, leading to faster attainment of target blood pressure reduction, reduced need for additional antihypertensive agents, lower rates of a composite of in-hospital mortality, invasive mechanical ventilation and unplanned ICU transfer, and shorter ICU and overall hospital stays, without a major increase in serious adverse events. These findings suggest that in real-world Indian emergency settings, where patients often present with longstanding, poorly controlled hypertension complicated by diabetes, coronary artery disease, stroke or renal dysfunction, nitroglycerin used within a clear protocol can provide safe and effective haemodynamic stabilisation. From a practical standpoint, hospitals should consider formally adopting and institutionalising a nitroglycerin-based hypertensive emergency protocol that specifies inclusion and exclusion criteria, starting doses, titration steps, monitoring frequency, and target mean arterial pressure reduction thresholds, rather than leaving drug choice and dosing entirely too individual discretion. Emergency and critical-care teams should be trained to recognise hypertensive emergencies early, rapidly assess for target-organ damage, and initiate nitroglycerin infusions with close haemodynamic monitoring, particularly in patients with acute pulmonary oedema or acute coronary syndromes, where the benefits of rapid afterload reduction are likely to be greatest. Nursing staff should receive focused training on bedside titration of nitroglycerin, recognition of early signs of hypotension and nitrate-related adverse effects, and documentation of vital signs and symptom trajectories, as their role is central to safe protocol implementation. At the same time, protocols should emphasise avoidance of overly aggressive blood pressure reduction, especially in patients with stroke or chronic kidney disease, by clearly defining maximum acceptable early drops in mean arterial pressure and requiring senior clinical review when thresholds are approached. Given the observed gains in ICU and hospital resource utilisation, hospital administrators and policy makers can justifiably support implementation of such protocols as part of broader quality-improvement initiatives, recognising their potential to free critical-care capacity and reduce costs. To sustain and extend these benefits, institutions should also link acute-care protocols with outpatient follow-up pathways, ensuring that patients discharged after a hypertensive emergency receive counselling on adherence, lifestyle modification, and appropriate long-term antihypertensive regimens, thereby reducing the risk of recurrence. Finally, although this study provides encouraging local evidence, multicentre collaborations should be fostered to refine protocol parameters, compare nitroglycerin-based approaches with other recommended intravenous agents, and generate uniform national guidance tailored to the Indian context.

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