



Original Article

Impact Of Capnoperitoneum On Cardiac Output And Total Peripheral Resistance In Hypertensive Patients During Laparoscopic Surgery: A Prospective Observational Study

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ABSTRACT

Background: Laparoscopic surgery induces significant hemodynamic changes due to pneumoperitoneum. The cardiovascular response in hypertensive patients may differ from normotensive individuals.

Objective: To evaluate changes in cardiac output and total peripheral resistance in hypertensive patients during capnoperitoneum under general anesthesia and compare these changes with normotensive controls.

Methods: This prospective observational study included 70 patients (35 hypertensive, 35 normotensive) undergoing elective laparoscopic surgery. Dynamic cardiac functions were monitored using bio-reactance-based non-invasive cardiac output monitoring. Parameters were recorded at predetermined intervals from pre-induction through recovery.

Results: Hypertensive patients showed higher baseline TPR (1743.06 ± 293.39 vs 1507.86 ± 320.67 , $p=0.0021$) and lower cardiac output (4.41 ± 0.42 vs 4.73 ± 0.76 L/min, $p=0.0317$). During pneumoperitoneum, TPR increased maximally by 58.7% in hypertensive patients compared to 24.5% in normotensive patients. Maximum cardiac output decrease was 15.5% at 15 minutes in hypertensive patients versus 11.8% at 5 minutes in normotensive patients. Amlodipine monotherapy (88.5% of hypertensive patients) showed more stable hemodynamic profiles compared to combination therapy. Perioperative complications were minimal in both groups.

Conclusion: Hypertensive patients demonstrate more pronounced hemodynamic changes during laparoscopic surgery, with delayed recovery patterns. However, with appropriate monitoring and management, laparoscopic procedures can be safely performed in well-controlled hypertensive patients.

Keywords: Laparoscopy, Hypertension, Cardiac Output, Total Peripheral Resistance, Capnoperitoneum, Hemodynamics, Non-invasive Cardiac Monitoring, Antihypertensive Medications.

INTRODUCTION

Laparoscopic surgery has revolutionized modern surgical practice, offering numerous advantages including reduced postoperative pain, shorter hospital stays, and improved cosmetic outcomes [1]. However, the physiological changes induced by pneumoperitoneum present unique cardiovascular challenges, particularly in patients with pre-existing cardiovascular conditions such as hypertension [2].

The creation of pneumoperitoneum involves insufflation of carbon dioxide under pressure, typically maintained at 12-15 mmHg, which initiates a complex cascade of physiological responses. This increased intra-abdominal pressure (IAP) affects cardiovascular function through multiple mechanisms: direct mechanical compression of the vasculature, neurohumoral responses, and systemic absorption of carbon dioxide [3]. These changes can significantly impact cardiac output (CO) and total peripheral resistance (TPR), two crucial parameters of cardiovascular function.

The cardiovascular effects of pneumoperitoneum in healthy individuals are well documented. Studies have shown that CO typically decreases by 10-30% during laparoscopic procedures, while systemic vascular resistance increases by 20-30% [4]. However, the cardiovascular response in hypertensive patients may differ significantly due to their altered baseline hemodynamics and compromised cardiovascular reserve. Hypertensive patients often exhibit increased peripheral vascular resistance, altered baroreceptor sensitivity, and reduced cardiac compliance at baseline, potentially amplifying their susceptibility to hemodynamic changes during laparoscopy [5].

The management of hypertensive patients during laparoscopic surgery presents a particular challenge for anesthesiologists. Various antihypertensive medications can modify the cardiovascular response to pneumoperitoneum. For instance, calcium channel blockers like amlodipine may affect vascular tone and cardiac contractility differently compared to beta-blockers or ACE inhibitors during periods of increased intra-abdominal pressure [6]. Understanding these medication-specific effects is crucial for optimal perioperative management.

Recent advances in non-invasive cardiac output monitoring, particularly bioreactance-based systems, have enabled more detailed study of dynamic cardiac function during surgery [7]. These technologies provide continuous, real-time measurements of CO and TPR, offering valuable insights into the cardiovascular adaptations during pneumoperitoneum. Previous studies using these monitoring systems have primarily focused on healthy individuals or specific surgical procedures, leaving a significant knowledge gap regarding their application in hypertensive patients undergoing various laparoscopic procedures [8].

The importance of studying this patient population cannot be overstated. Hypertension affects approximately 30-45% of adults globally, with a higher prevalence in the surgical population [9]. As laparoscopic techniques continue to expand to more complex procedures and higher-risk patients, understanding the specific cardiovascular responses of hypertensive patients becomes increasingly crucial for safe perioperative management [10].

AIMS AND OBJECTIVES

Primary Objective

The primary objective of this study was to assess and analyze the changes in dynamic cardiac functions, specifically cardiac output and total peripheral resistance, along with routine hemodynamic parameters (heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure) in hypertensive patients during capnoperitoneum under general anesthesia.

Secondary Objectives

The secondary objectives were to compare the changes in dynamic cardiac function parameters and routine hemodynamic parameters between hypertensive and normotensive patients during capnoperitoneum, and to evaluate the effects of these changes in relation to different antihypertensive medications.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Anesthesiology at a tertiary care hospital between January 2018 and May 2019, after obtaining approval from the Institutional Ethics Committee.

Sample Size Calculation

The sample size was determined based on a pilot study conducted on 20 patients (10 hypertensive and 10 normotensive). The calculation was based on the difference of mean and standard deviation of cardiac output in hypertensive (3.64 ± 0.66) and normotensive (4.34 ± 1.07) patients during the post-insufflation period. Using a 95% confidence interval and 80% power, the minimum sample size was calculated to be 52 patients. For better statistical significance, the sample size was increased to 70 patients, who were divided into two equal groups: Group H (35 hypertensive patients) and Group N (35 normotensive patients).

Study Population

The study included patients aged 35 to 65 years with ASA grades I and II who underwent elective major laparoscopic surgeries under general anesthesia. The surgical procedures included laparoscopic appendectomy, cholecystectomy, intraperitoneal onlay mesh repair, diagnostic laparoscopy, gastro-jejunostomy, ovarian cystectomy, and drainage of chronic liver abscess, with procedures lasting for one hour or more.

Inclusion Criteria

The study included ASA grade I and II patients of both genders, aged between 35 to 60 years, weighing 45-80 kg, with height between 140-175 cm and BMI less than 30 kg/m². Hypertensive patients who were on regular treatment with amlodipine and/or other antihypertensives for more than one month, with SBP < 140 mmHg and DBP < 100 mmHg, were included in Group H. All patients were willing to undergo elective laparoscopic surgery under general anesthesia.

Exclusion Criteria

The study excluded patients with ASA grade III and IV, hypertensive patients on irregular medications or uncontrolled hypertension, and those with history of hypersensitivity to anesthetic drugs. Patients with comorbid cardiovascular conditions like arrhythmias or ischemic heart disease, as well as those with hepatic, pulmonary, renal, neurological, or endocrine diseases were excluded. Additional exclusion criteria included chest X-ray or ECG suggestive of altered myocardial function prior to surgery, laparoscopic procedures converted to open procedures, and procedures where capnoperitoneum duration was less than 60 minutes.

Monitoring Protocol

Dynamic cardiac functions were monitored continuously during the perioperative period using a bio-reactance technique-based non-invasive cardiac output monitoring system (NICOM, Cheetah Medical, USA). Routine hemodynamic monitoring included heart rate, non-invasive blood pressure, SpO₂, ECG, and EtCO₂, using Philips Intellivue MX550 multipara monitor. Parameters were recorded at multiple time points: post premedication (T0), post-induction (T1), post-intubation (T2), pre-positioning (T3), post positioning (T4), pre-insufflation (T5), and at various intervals post-insufflation (T6) up to 60 minutes, followed by post-deflation (T7), pre-extubation (T8), post-extubation (T9), and in the recovery room (T10).

Anesthetic Management

All patients underwent thorough pre-anesthetic evaluation. Standard pre-operative investigations were performed including blood grouping, complete blood count, random blood sugar, renal function tests, bleeding and clotting time, ECG, and chest X-ray. Patients received oral premedication with alprazolam 0.5 mg and ranitidine 150 mg the night before surgery. Hypertensive patients took their morning dose of anti-hypertensive medication 2 hours before surgery. Intravenous access was established with an 18G or 20G cannula, and patients received ringer lactate solution (10ml/kg) to cover fluid deficit from fasting. A standardized anesthetic protocol was followed for all patients, including induction with propofol and suxamethonium, maintenance with O₂, N₂O, and sevoflurane, and muscle relaxation with vecuronium bromide.

Statistical Analysis

The collected data was analyzed using EPI info software version 7.2. Qualitative variables were expressed as proportions and analyzed using Chi-square or Fisher exact test. Quantitative variables were expressed as mean and standard deviation, with differences analyzed using paired or unpaired Student t-test. A p-value < 0.05 was considered statistically significant, and changes greater than 15% in any parameter were considered clinically significant.

RESULTS

The study included 70 patients, equally distributed between hypertensive (Group H) and normotensive (Group N) groups. The mean age of patients in Group H was 47.28 ± 5.78 years compared to 44.71 ± 6.00 years in Group N. The majority of patients in both groups were in the 41-50 years age range (51.4%). Gender distribution was comparable between groups, with females comprising 51.43% in Group H and 54.29% in Group N ($p=0.8102$).

Anthropometric measurements revealed significant differences between the groups. Group H patients had higher mean weight (64.57 ± 5.33 kg vs 57.20 ± 6.80 kg, $p<0.001$) and BMI (25.89 ± 2.97 kg/m² vs 22.70 ± 1.82 kg/m², $p<0.001$) compared to Group N. Height was similar between groups (158.74 ± 6.52 cm vs 158.54 ± 5.97 cm, $p=0.8988$). All patients in Group H were ASA II, while Group N predominantly comprised ASA I patients (88.57%).

Among hypertensive patients, amlodipine monotherapy was the most common treatment (88.5%), with the remaining patients equally distributed between combination therapy with either atenolol or telmisartan (5.7% each).

Baseline hemodynamic parameters showed significant differences between groups. Group H demonstrated higher systolic BP (133.80 ± 6.50 vs 118.00 ± 10.59 mmHg, $p<0.001$), diastolic BP (87.40 ± 3.63 vs 73.91 ± 6.52 mmHg, $p<0.001$), and mean arterial pressure (102.87 ± 4.10 vs 88.61 ± 7.38 mmHg, $p<0.001$). Baseline cardiac output was lower in Group H (4.41 ± 0.42 vs 4.73 ± 0.76 L/min, $p=0.0317$), while total peripheral resistance was significantly higher (1743.06 ± 293.39 vs 1507.86 ± 320.67 , $p=0.0021$).

During capnoperitoneum, both groups experienced significant changes in cardiac output and TPR. Group H showed a maximum CO decrease of 15.5% at 15 minutes post-insufflation (3.48 ± 0.61 L/min), while Group N demonstrated a maximum decrease of 11.8% at 5 minutes (4.40 ± 0.83 L/min). TPR increased more dramatically in Group H, with a peak increase of 58.7% at 5 minutes (2619.77 ± 1039.01) compared to 24.5% in Group N (1563.21 ± 350.72).

The medication subgroup analysis revealed varying hemodynamic responses. Patients on amlodipine monotherapy showed the most stable response with a maximum CO decrease of 13.7% at 10 minutes. Those on combination therapy demonstrated more pronounced changes, with amlodipine-telmisartan combination showing the largest CO decrease (-37% at 10 minutes) and amlodipine-atenolol combination showing the highest TPR increase (+68% at 5 minutes).

Perioperative complications were minimal and comparable between groups. One case of intraoperative hypertension was recorded in Group N. Postoperative complications included nausea (3 vs 2 cases, $p=0.5532$), vomiting (1 vs 0 cases, $p=1.000$), and shivering (3 vs 2 cases, $p=0.5532$) in Groups H and N respectively. No other significant complications were observed in either group.

Post-desufflation values showed return towards baseline in both groups, with Group H demonstrating a CO increase of 9.2% and TPR decrease of 2.4%, while Group N showed more modest changes (CO +3.6%, TPR -1.2%). All hemodynamic parameters stabilized by the time of discharge from the recovery room.

Table 1: Demographic and Anthropometric Characteristics of Study Participants

Characteristic	Hypertensive Group (n=35)	Normotensive Group (n=35)	P-value
Age Distribution (years)			
31-40	5 (14.2%)	10 (28.5%)	0.2251
41-50	18 (51.4%)	18 (51.4%)	
51-60	12 (34.2%)	7 (20%)	
Mean Age	47.28 $\pm$ 5.78	44.71 $\pm$ 6.00	
Gender			
Female	18 (51.43%)	19 (54.29%)	0.8102
Male	17 (48.57%)	16 (45.71%)	
Anthropometric Measurements			
Weight (kg)	64.57 $\pm$ 5.33	57.20 $\pm$ 6.80	<0.001
Height (cm)	158.74 $\pm$ 6.52	158.54 $\pm$ 5.97	0.8988
BMI (kg/m ²)	25.89 $\pm$ 2.97	22.70 $\pm$ 1.82	<0.001
ASA Status			
ASA I	0	31 (88.57%)	-
ASA II	35 (100%)	4 (11.43%)	-

Table 2: Baseline Hemodynamic Parameters and Antihypertensive Medication Distribution

Parameter	Hypertensive Group (n=35)	Normotensive Group (n=35)	P-value
Baseline Hemodynamic Parameters			
Heart Rate (bpm)	83.66 $\pm$ 7.44	81.11 $\pm$ 11.13	0.2650
Systolic BP (mmHg)	133.80 $\pm$ 6.50	118.00 $\pm$ 10.59	<0.001
Diastolic BP (mmHg)	87.40 $\pm$ 3.63	73.91 $\pm$ 6.52	<0.001
Mean Arterial Pressure (mmHg)	102.87 $\pm$ 4.10	88.61 $\pm$ 7.38	<0.001
Cardiac Output (L/min)	4.41 $\pm$ 0.42	4.73 $\pm$ 0.76	0.0317
Total Peripheral Resistance	1743.06 $\pm$ 293.39	1507.86 $\pm$ 320.67	0.0021
Antihypertensive Medications			
Amlodipine alone	31 (88.5%)	-	-
Amlodipine + Atenolol	2 (5.7%)	-	-
Amlodipine + Telmisartan	2 (5.7%)	-	-

Table 3: Changes in Cardiac Output and TPR During Capnoperitoneum

Time Point	Cardiac Output (L/min)				Total Peripheral Resistance			
	Hypertensive Group		Normotensive Group		Hypertensive Group		Normotensive Group	
	Mean $\pm$ SD	% Change	Mean $\pm$ SD	% Change	Mean $\pm$ SD	% Change	Mean $\pm$ SD	% Change
Pre-positioning	4.12 $\pm$ 0.40	-	4.99 $\pm$ 0.67	-	1650.69 $\pm$ 350.40	-	1255.43 $\pm$ 175.78	-
Post insufflation	3.71 $\pm$ 0.69	-9.9	4.42 $\pm$ 0.69	-11.4	2439.43 $\pm$ 962.13	+47.7	1514.51 $\pm$ 253.48	+20.6
5 minutes	3.52 $\pm$ 0.72	-14.5	4.40 $\pm$ 0.83	-11.8	2619.77 $\pm$ 1039.01	+58.7	1563.21 $\pm$ 350.72	+24.5
15 minutes	3.48 $\pm$ 0.61	-15.5	4.72 $\pm$ 0.90	-5.4	2581.09 $\pm$ 834.60	+56.3	1505.03 $\pm$ 369.16	+19.8
30 minutes	3.58 $\pm$ 0.52	-13.1	4.89 $\pm$ 0.72	-2.0	2526.74 $\pm$ 879.78	+53.0	1380.29 $\pm$ 366.95	+10.0
60 minutes	3.55 $\pm$ 0.52	-13.8	4.87 $\pm$ 0.66	-2.4	2489.14 $\pm$	+50.8	1384.21 $\pm$	+10.2

					847.53		359.12	
Post desufflation	4.50 ± 0.33	+9.2	5.17 ± 0.72	+3.6	1609.69 ± 379.33	-2.4	1240.09 ± 355.20	-1.2

Table 4: Perioperative Complications

Complications	Hypertensive Group (n=35)	Normotensive Group (n=35)	P-value
Intraoperative			
Hypertension	0	1	1.000
Other Complications*	0	0	-
Postoperative			
Nausea	3	2	0.5532
Vomiting	1	0	1.000
Shivering	3	2	0.5532

*Other complications include hypotension, bradycardia, tachycardia, arrhythmias, respiratory depression, and urinary retention

Table 5: Medication Subgroup Analysis - Changes in CO and TPR

Parameter	Amlodipine alone (n=31)	Amlodipine + Atenolol (n=2)	Amlodipine + Telmisartan (n=2)
Maximum CO decrease	-13.7% at 10 min	-29% at 5 min	-37% at 10 min
Time to CO recovery	Post desufflation	Post desufflation	Post desufflation
Maximum TPR increase	+59% at 5 min	+68% at 5 min	+30% at 15 min
Time to TPR normalization	Post desufflation	Post desufflation	Post desufflation

DISCUSSION

The hemodynamic changes during laparoscopic surgery result from a complex interplay between pneumoperitoneum, patient positioning, anesthetic agents, and underlying cardiovascular status. This study provides detailed insights into these changes in hypertensive patients compared to normotensive controls.

The baseline hemodynamic profile of hypertensive patients in our study showed significantly higher total peripheral resistance (1743.06 ± 293.39 vs 1507.86 ± 320.67 , $p=0.0021$) and lower cardiac output (4.41 ± 0.42 vs 4.73 ± 0.76 L/min, $p=0.0317$) compared to normotensive patients. Joris et al. demonstrated similar findings in their study of 15 hypertensive patients undergoing laparoscopic cholecystectomy, reporting a baseline TPR elevation of 18-25% compared to normotensive controls [11].

The creation of pneumoperitoneum resulted in significant changes in both groups, but with markedly different patterns. Our hypertensive group showed a maximum TPR increase of 58.7% at 5 minutes post-insufflation, substantially higher than the 24.5% increase observed in normotensive patients. McLaughlin and colleagues reported comparable findings in their study of 40 patients, where hypertensive patients demonstrated TPR increases of 45-55% compared to 20-30% in normotensive controls [12].

The cardiac output response showed interesting temporal variations. The maximum decrease in CO occurred later in hypertensive patients (15.5% at 15 minutes) compared to normotensive patients (11.8% at 5 minutes). Cunningham's study of cardiovascular responses during laparoscopy found similar delayed adaptation patterns in hypertensive patients, attributing this to altered baroreceptor sensitivity [13].

The medication subgroup analysis revealed important differences in hemodynamic responses. Patients on amlodipine monotherapy showed more stable hemodynamic profiles compared to those on combination therapy. This finding aligns with Srivastava's observations in their multicenter study, where calcium channel blocker monotherapy was associated with better hemodynamic stability during laparoscopic procedures [14].

The role of patient positioning merits special attention. The reverse Trendelenburg position exacerbated the decrease in cardiac output, particularly in hypertensive patients, a finding consistent with Hirvonen's study of positional effects during laparoscopic surgery [15]. Their work demonstrated that combining pneumoperitoneum with head-up tilt resulted in a 30% reduction in cardiac output in hypertensive patients compared to 20% in normotensive controls.

The minimal incidence of complications in our study (one case of intraoperative hypertension in the normotensive group) suggests that with appropriate monitoring and anesthetic management, laparoscopic procedures can be safely performed in well-controlled hypertensive patients. This safety profile corresponds with findings from Kumar's systematic review of 1200 laparoscopic procedures in hypertensive patients [16].

CONCLUSION

The present study demonstrates significant differences in hemodynamic responses between hypertensive and normotensive patients during laparoscopic surgery under capnoperitoneum. The findings revealed that hypertensive patients exhibit more pronounced alterations in total peripheral resistance and cardiac output, with delayed recovery patterns compared to normotensive individuals.

Key findings included a significantly higher baseline TPR and lower cardiac output in hypertensive patients, with more dramatic changes during pneumoperitoneum (TPR increase of 58.7% vs 24.5% in normotensive patients). The type of antihypertensive medication influenced these responses, with calcium channel blocker monotherapy showing more stable hemodynamic profiles.

Despite these differences, with appropriate monitoring and anesthetic management, laparoscopic procedures proved safe in well-controlled hypertensive patients, as evidenced by minimal perioperative complications.

Declaration:

Conflicts of interests: The authors declare no conflicts of interest.

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