Effect of stellate ganglion block versus intraluminal application of verapamil-nitroglycerine solution on internal mammary artery graft blood flow rate in patients undergoing on-pump coronary artery bypass grafting

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Background

Left internal mammary artery (IMA) graft is the most promising arterial conduit for coronary artery bypass grafting. Stellate ganglion block (SGB) induces sympathetic blockade and is used to prevent or control spasm of the internal mammary artery. The purpose of this study was to investigate the effect of left SGB on left IMA blood flow rate.

Patients and methods

A total of 170 patients aged between 65 and 70 years, with American Association of Anesthesiologists physical status II and III, and scheduled for elective coronary artery bypass grafting, were randomly allocated to either a SGB group or a verapamil-nitroglycerine group. In the SGB group, the patients received SGB using 8 ml of bupivacaine 0.25%. In the verapamil-nitroglycerine group, the patients received intraluminal injection of the harvested IMA graft with a solution, containing verapamil 5 mg, nitroglycerine 2.5 mg, heparin 500 U, 8.4% $NAHCO_3$ 0.2 ml, and ringer solution 40 ml, throughout its whole length using a small syringe, and with a low dose of intravenous nicardipine infusion started after harvesting (5 mg nicardipine in 100 ml saline at a rate of 0.5 mg or 10 ml/h). IMA blood flow rate (primary outcome), abnormal ECG changes, ICU length of stay, intra-aortic balloon usage, pre–postoperative pulse rate and blood pressure, incidence of atrial fibrillation, radio-femoral arterial pressure difference, pre–postoperative ejection fraction, need for re-exploration, and mortality rate were observed.

Results

This prospective study showed a significant increase of IMA blood flow rate ($P<0.001$) and nonsignificant decrease in mortality rate in the SGB group compared with the verapamil-nifedipine group. There was no significant difference between the two groups regarding ICU length of stay, re-exploration, intra-aortic balloon usage, preoperative and postoperative mean pulse rate, preoperative and postoperative mean blood pressure, and preoperative and postoperative ejection fractions between study groups. The incidence of atrial fibrillation ($P=0.030$) and abnormal ECG changes ($P=0.043$) was significantly lower in SGB group. Radio-femoral pressure difference was significantly lower in SGB group at 20 and 40 min after cardiopulmonary bypass.

Conclusion

The results of this study showed that SGB prevents IMA spasm, increases its blood flow rate, and decreases incidence of atrial fibrillations compared with intraluminal injection of verapamil and nitroglycerine combined with intravenous nicardipine.

Keywords:
coronary artery bypass graft, internal mammary artery, nitroglycerine, stellate ganglion block, verapamil

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Introduction

Internal mammary artery (IMA) graft is a more popular arterial graft compared with saphenous vein graft for myocardial revascularization in coronary artery bypass. It is characterized by long-term patency, which results in lower mortality rates and excellent postoperative outcomes [1]. However, the arterial conduit spasm is always a frustrating complication in coronary artery bypass surgeries, as it can be lethal owing to its catastrophic hemodynamic consequences, with an incidence of 0.43% [2]. The mechanism of graft spasm is still unexplained [2]. The systemic or topical application of various pharmacological agents, such as calcium antagonists or nitroglycerine, has been proven to reverse or avoid spasm but is unfortunately associated with alarming adverse effects [3]. Stellate ganglion block (SGB) application using local anesthetics is effective in the pain management and treatment of vascular spastic conditions of the upper limb owing to its sympatholytic effect [4]. Regrettably, few studies have investigated the effect of SGB on the spasm of IMA grafts [5]. An earlier study by Koyama *et al.* [6] stated that SGB suppressed cardiac sympathetic function without any significant effect on blood pressure.

The aim of this prospective study was to evaluate the effect of left SGB compared with the intraluminal injection of verapamil combined with nitroglycerine on the left internal artery blood flow rate, the incidence of atrial fibrillations, ICU stay length, and incidence of postoperative adverse events.

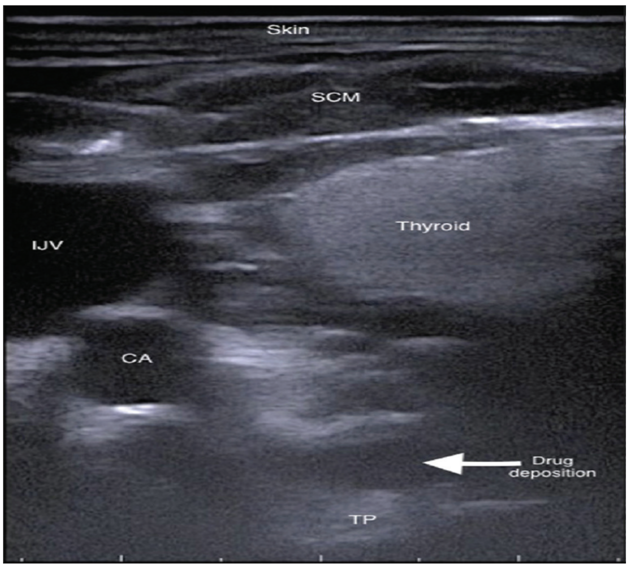
Patients and methods

The study was approved by the ethics committee of Ain Shams University (reference no. FWASU R 27/2018), and written informed consent was obtained from each patient. This prospective, randomized, parallel-group study was conducted with 170 patients between 65 and 70 years old, with American Association of Anesthesiologists physical status II or III, scheduled for elective coronary artery bypass grafting (CABG) by the same surgical team. Operations were carried out in Ain Shams University Hospital cardiothoracic academy from November 2018 to November 2019. Patients with existing coagulopathy, recent myocardial infarction, pathological bradycardia (heart rate<60 beats/min), unstable angina, impaired ventricular function (ejection fraction <40%), emergency CABG, left main coronary artery disease, and contralateral phrenic nerve palsy were not eligible to participate in this study. The inclusion criteria were age between 65 and 70 years old; patients with ejection fraction more than 40%; absence of heart failure or chronic obstructive lung disease; and elective CABG.

Preanesthetic evaluation and routine investigations were carried out the night of surgery. In addition, all patients underwent elective left internal mammary artery (LIMA) angiography and echocardiography in conjugation with cardiac consultation. Patients fasted for 6–8 h. Intraoperative transesophageal Echo was performed by an experienced cardiac anesthesiologist throughout the whole surgery.

All patients were administered standard general anesthesia. Midazolam premedication was limited to 0.05 mg/kg intravenous. Anesthesia was induced with 12 μg/kg fentanyl, 5–7 mg/kg sodium thiopental, and 0.15 mg/kg pancuronium and was maintained with isoflurane 1–2.0%. Heart rate and blood pressure were maintained within 20% of the baseline values. Patients were randomly allocated either to the SGB group or to the verapamil-nitroglycerine group according to a computerized randomization code, with allocation ratio 1 : 1. In the SGB group (n=85), patients were placed in the spine position, head to the right side with neck extension. First, the C6 vertebral body was spotted at the level of the cricoid cartilage, and next, the C6 anterior tubercle, named the carotid tubercle, was palpated. Later, pressure was applied to depress the lung dome to avoid pneumothorax. A 22 G needle was inserted toward the carotid tubercle and advanced inferomedially to the C6 body. Once it touched the body, it was withdrawn 1–2 mm, and 8 ml of bupivacaine 0.25% was injected (after negative aspiration for blood), as shown in Fig. 1. The correct placement of the needle and spread of bupivacaine were confirmed by rapid increase of the left index's skin temperature by 1.5°C compared with the baseline value; the block was performed by the same well-trained anesthesiologist. The verapamil-nitroglycerine group (n=85) underwent intraluminal injection of the harvested IMA graft with the solution containing verapamil 5 mg, nitroglycerine 2.5 mg,

Figure 1



Ultrasound image of SGB. A 22 G needle was inserted toward the carotid tubercle and advanced inferomedially to the C6 body. Once it touched the body, it was withdrawn 1–2 mm and 8 ml of bupivacaine 0.25% was injected. CA, carotid artery; IJV, internal jugular vein; SCM, sternocleidomastoid; SGB, stellate ganglion block; TP, transverse process of C6 vertebra.

heparin 500 U, 8.4% $NAHCO_3$ 0.2 ml, and Ringer solution 40 ml throughout its whole length using a small syringe, followed by a low dose of intravenous nicardipine infusion (5 mg nicardipine in 100 ml saline at a rate of 0.5 mg or 10 ml/h) performed after initiation of harvesting. The IMA pedicle was also wrapped in the solution-soaked sponge. In case of the incidence of vasospasm, ITA flow volume was markedly reduced after mobilization from the chest wall. This vasospasm was caused by surgical dissection of the artery as well as physical factors such as diathermy or exposure to cold. The artery dilated, and its flow markedly improved following the intraluminal and topical administration of pharmacologic agents such as nitroglycerin-verapamil and was assessed by free flow measurement in this study.

After 1 h of SGB performance, cardiopulmonary bypass (CPB) was established. All patients had median sternotomy. Anticoagulation was achieved with heparin 300 U/kg administered into the right atrium to maintain an activated clotting time above 480 s. CPB was conducted with nonocclusive roller pumps, membrane oxygenators, arterial line filtration, and cold blood-enriched hyperkalemic arrest. The CPB circuit was primed with 1.8 l lactated Ringer's solution and 50 ml of 20% mannitol. Management of CPB included systemic hypothermia (esophageal temperature 32°C) during aortic cross-clamping, targeted perfusion pressure between 60 and 80 mmHg, and pump flow rate of 2.2 $l/min/m^2$. Myocardial protection was achieved with antegrade cold blood cardioplegia. A 32-μm filter (Avecor Affinity, Minneapolis, Minnesota, USA) was used in the arterial perfusion line. Before separation from the CPB, patients were warmed to 36–37°C. After separation from the CPB, heparin was neutralized with protamine sulfate (1 mg/100 U heparin) to reach an activated clotting time within 10% of baseline. All patients were transferred to the ICU after surgery.

The primary end point

Mean blood flow measurement

Five minutes after systemic heparinization, the free flow from the distal cut end of the IMA was determined by allowing the IMA to bleed into an open beaker for 1 min and measuring the volume per min. The IMA was then occluded gently with a bulldog clamp (flow 1), known as timed volumetric collections of the cut end of the IMA. Before the start of CPB, the flow of the IMA was repeated (flow 2). Before measurement of IMA blood flow, none of the patients received phenylephrine or norepinephrine infusion. IMA blood flow was measured while mean arterial blood pressure was maintained between 70 and 75 mmHg.

Secondary endpoints

Evidence of postoperative electrocardiogram changes such as postoperative cardiac arrhythmia as ventricular fibrillations, ventricular tachycardia, and S-T segment elevation (time frame: up to 7 days); ICU stay length; need for intra-aortic balloon pumping; need for inotropic drugs postoperatively; postoperative atrial fibrillation; pre–postoperative pulse rate and blood pressure; radio-femoral arterial pressure difference; pre–postoperative ejection fraction; and 30-day postoperative mortality rate were the secondary endpoints. All cardiac parameters were measured by the same expert cardiologist.

Sample size calculation

Power Calculations and Sample Size software (PASS; NCSS, LLC, East Kaysville, Utah, USA) revealed that 170 patients, 85 per arm, were needed after considering a 5% dropout (power of 80%, alpha error at 5%). These calculations were based on a previous study [5], which showed that the mean blood flow was 47.3±3.4 and 60.5±5.2 ml/min in the non-SGB and SGB groups, respectively.

Statistical analysis

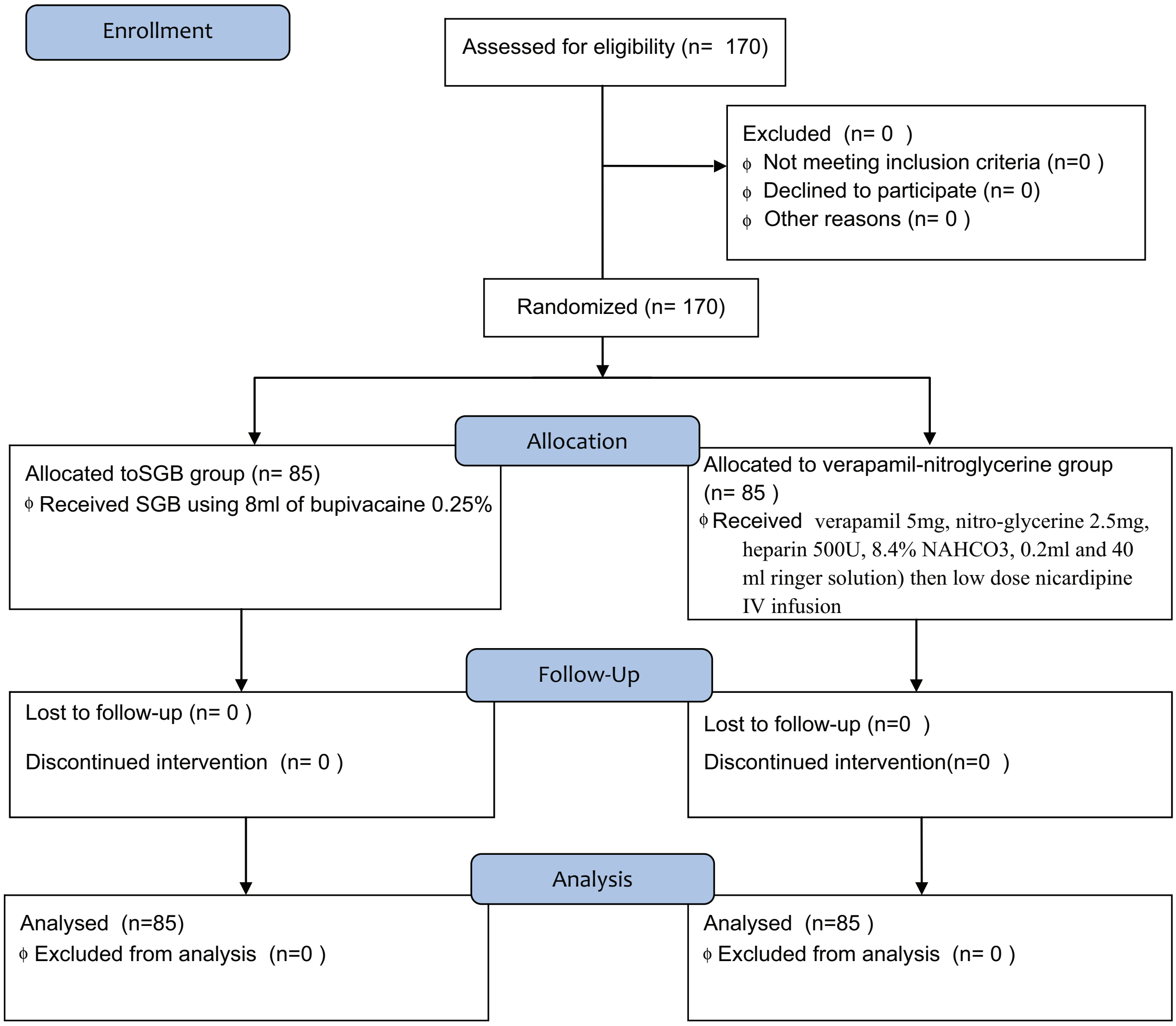
The collected data were coded and tabulated, and statistical analysis was performed using the SPSS software package, version 17.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were carried out for numerical parametric data and presented as mean ±SD, whereas categorical data are presented as number and percentage. Variables such as demographic data and comorbidities were compared using the χ^2 test. A P value less than 0.05 was considered statistically significant.

Results

A total of 170 patients were assessed for eligibility and were all enrolled in our study with no single case of protocol violation as shown in the consort flow diagram (Fig. 2). They were randomized, and their data were analyzed. The research team decided to exclude patients according to their clinical condition or in cases of violation of the protocol.

The demographic and surgical data in addition to comorbidities were comparable between the study groups (Table 1). There was no significant

Figure 2



Study flow chart.

difference regarding preoperative mean blood pressure, pulse rate, preoperative ejection fraction, and need for re-exploration between the study groups (Table 1).

The intention-to-treat analysis of the primary outcome revealed that the IMA blood flow rate was 57.33 ±1.96 ml/min in SGB patients and 44.89±1.9 ml/min in verapamil-nifedipine patients; the IMA blood flow rate was significantly higher in the SGB group than in the verapamil-nifedipine group (Table 2). The incidence of abnormal ECG changes was significantly higher in in the verapamil-nifedipine group compared with SGB group (P=0.043) (Table 2).

There was no significant difference between the groups regarding the length of ICU stay and intra-aortic balloon usage (P=0.281 and 0.650, respectively) (Table 2). The mortality rate was comparable between the study groups (P=0.560) (Table 2). The incidence of atrial fibrillations was significantly higher in verapamil-nifedipine group compared with SGB group (P=0.030) (Table 2).

Postoperative mean blood pressure and pulse rate values were comparable between the study groups (P=0.080 and 0112, respectively) (Table 2). There was no significant difference between the groups regarding postoperative ejection fraction (P=0.172) (Table 2). The need for inotropic support and the ventilation time were comparable between the study groups (P=0.119 and 0.203, respectively) (Table 2).

There was no significant difference between the groups regarding radio-femoral arterial pressure difference at baseline, 60 min after CPB, on admission to ICU, and 10 min after admission (P=0.166, 0.294, 174, and 0.408, respectively) (Table 3).

Table 1 Demographic, surgical data, and comorbidities

Demographic data	SGB group (*N*=85)	Verapamil-nifedipine group (*N*=85)	*P* value
Sex			
Female	38 (44.7)	42 (49.4)	0.539
Male	47 (55.3)	43 (50.6)	
Age (years)	68.32±2.09	67.76±2.22	0.097
ASA			
II	51 (60.0)	57 (67.1)	0.339
III	34 (40.0)	28 (32.9)	
Procedure duration (min)	456.86±4.98	455.46±6.21	0.107
Cross-clamp time (min)	65.98±10.73	68.94±11.55	0.085
CPB time (min)	141.14±1.19	141.15±1.18	0.948
Hypertension	33 (38.8)	28 (32.9)	0.424
Diabetes mellitus	17 (20.0)	22 (25.9)	0.362
Number of grafts			
Single graft	10 (11.8)	9 (10.6)	0.896
2 grafts	29 (34.1)	27 (31.8)	
3 grafts	46 (54.1)	49 (57.6)	
Preoperative EF (%)	53.96±2.74	54.64±2.57	0.102
Preoperative mean blood pressure	68.07±1.46	67.71±1.54	0.115
Preoperative mean pulse rate	72.53±3.52	73.07±3.53	0.318
Re-exploration	2 (2.4)	3 (3.5)	0.650

All data were presented as *n* (%)except age, procedural duration, cross-clamp, and cardiopulmonary bypass time that were presented as mean±SD. ASA, American Association of Anesthesiologists; CPB, cardiopulmonary bypass; EF, ejection fraction; SGB, stellate ganglion block.

Table 2 Internal mammary artery blood flow rate, S-T segment depression, ICU length of stay, intra-aortic balloon usage, atrial fibrillation, and mortality rate: comparison between the study groups

	SGB group (*N*=85)	Verapamil-nifedipine group (*N*=85)	*P* value
IMA blood flow rate (ml/min)	57.33±1.96	44.89±1.9	<0.001**
Abnormal postoperative ECG changes	0	4 (4.7)	0.043*
ICU stay length (days)	2.47±0.5	2.39±0.49	0.281
	2–3	2–3	
Intra-aortic balloon usage	2 (2.4)	3 (3.5)	0.650
Incidence of AF	1 (1.2)	7 (8.2)	0.030*
30-day postoperative mortality rate	1 (1.2)	2 (2.4)	0.560
Postoperative EF (%)	59.99±0.76	59.74±1.47	0.172
Postoperative mean blood pressure	78.82±1.22	79.29±2.14	0.080
Postoperative mean pulse rate (beats/min)	93.25±4.41	94.2±3.28	0.112
Need for inotropic support	3 (3.5)	8 (9.4)	0.119
Ventilation time (h)	10.06±0.9	10.24±0.9	0.203

All data were presented as *n* (%)except IMA blood flow rate, mean blood pressure, mean pulse rate, ventilation time and length of ICU stay that were presented as mean±SD. AF, atrial fibrillations; EF, ejection fraction; IMA, internal mammary artery; SGB, stellate ganglion block. **Highly significant. *Significant.

Table 3 Mean radio-femoral arterial pressure difference: comparison between groups

	SGB group (*N*=85)	Verapamil-nifedipine group (*N*=85)	*P* value
Duration (min): baseline	2.73±0.65	2.87±0.61	0.166
Post-CPB (min)			
Post-CPB 20	−1.05±1.18	−1.86±1.15	<0.001**
Post-CPB 40	−0.97±1.16	−1.44±1.05	0.005*
Post-CPB 60	−1.36±0.93	−1.2±1.08	0.294
Post-CPB On ICU admission	−0.32±0.92	−0.50±0.86	0.174
Post-CPB 10 min after admission	−0.31±0.74	−0.41±0.79	0.408

All data were presented as mean±SD. CPB, cardiopulmonary bypass; SGB, stellate ganglion block. *Significant. **Highly significant.

Radio-femoral arterial pressure difference was significantly lower in SGB group at 20 and 40 min after CPB (*P*<0.001 and *P*=0.005, respectively) (Table 3).

Discussion

Arterial grafts are the most popular conduits for myocardial revascularization in CABG [1]. The strength of this study is derived from being one of the first trials discussing the efficacy of SGB in improving IMA blood flow rate and reducing abnormal ECG changes after CABG.

The results of this prospective study showed that SGB is a feasible option for prevention of IMA spasm in elderly patients undergoing CABG. This was shown by a significant increase in IMA blood flow rate in addition to a significant reduction in the incidence of atrial fibrillations or ECG changes in the SGB group. There were no significant differences between the study groups regarding the incidence of the length of ICU stay and intra-aortic balloon usage.

The most aggravating adverse event following arterial conduit harvesting was the perioperative graft spasm caused by increased α-adrenergic activity or increase in blood pH, systemic hypothermia, local manipulation of the artery, endothelial dysfunction, enhanced platelet activity, release of vasoconstrictor substances, elevation of histamine and vasopressin levels, and elevation of potassium levels [7].

Following the isolation of the vessel, vasospasm occasionally occurs leading to reduced early graft blood flow and resulting in perioperative morbidity and mortality [8]. This annoying problem can be either reversed or prevented by various intraluminal or topical vasodilators [8].

SGB is a safe, feasible, and effective procedure with minimal complications reported at ~0.17% [4]. The stellate ganglion innervates the nerve bundles that extend along the IMA [9]. The site of these nerve fibers plays a vital role in the surgical management of myocardial ischemia [10]. SGB is important for the prevention and control of perioperative hypertension induced by sympathetic activity [11]. Importantly, SGB has been shown to alleviate refractory angina pain unresponsive to medical treatment or revascularization [12].

The SGB technique is effective for treatment of spastic vascular disorders because it induces vasodilatation, thus increasing blood flow [13].

Dihydropyridine derivatives are the most effective spasmolytic drug so they are preferred for use in CABG particularly if radial artery graft is harvested. Recently, nicardipine, one of dihydropyridine derivatives, replaced verapamil for intravenous use in CABG [14].

Calcium antagonists such as nicardipine effectively prevent potassium-mediated spasm in both IMA [15] and radial artery [3].

After reviewing the literature, few studies seem to support the findings of the present study and confirm the efficacy and safety of this blockage. In a study by Yildrim *et al.* [5], SGB prevents IMA spasm which was evidenced by significantly lower incidence of S-T segment depression and postoperative atrial fibrillation. The use of inotropic agents was significantly restricted in the SGB group. It was emphasized that preemptive SGB reversed right atrial spasm, which increased right atrial blood flow leading to better surgical outcomes in patients undergoing CABG [5]. These findings support the findings of the current study.

A study by Sasson *et al.* [16] showed that vasodilators such as nifedipine, verapamil, and glyceryl trinitrate had no remarkable effect on IMA blood flow rate. A prospective study by Gopal *et al.* [17] found that SGB significantly increased LIMA graft diameter ($P<0.0001$) without causing any remarkable hemodynamic complications. For this reason, it could be used as a suitable alternative to vasodilating agents. These findings agreed with the findings of the present study.

Various pharmacological agents such as nitrates and calcium channel blockers are commonly used for the prevention of LIMA spasm, but their use is associated with several limitations as shown by a few studies [18]. The preemptive administration of verapamil is associated with minor effects on the induced right atrial contraction. In contrast, nitroglycerine was found effective for the reversal of the established right atrial contractions [19].

Several studies have revealed that human IMA mainly incorporates α1-adrenoceptors; therefore, contractions are mediated by α-adrenoceptor agonists through activation of the α1-adrenoceptors [20].

An earlier study showed that SGB prevents the incidence and stops the maintenance of atrial fibrillation, through the control of the immune and autonomic systems [21]. SGB stops the stress response through decreasing inflammatory mediators' production, which prevent the electrical and structural remodeling of cardiac muscle cells, thus decreasing the incidence of atrial fibrillation [21]. Application of the ultrasound-guided SGB facilitates the block, increasing its efficacy and reducing the volume of injection and the risk of esophageal, neuronal, or vascular injury by direct visualization of the site of injection [22].

He *et al*. [23] reported that IMA spasm results from some metabolic abnormalities such as hypercalcemia, hypomagnesemia, hypokalemia, and increased serum lactates.

The manipulation of coronary arteries during cardiac surgery initiates postganglionic sympathetic fiber stimulation, which resembles stellate ganglion stimulation. For this reason, SGB can stop this reflex by reducing the efferent cervical sympathetic discharge and causes vasodilatation of IMA [24].

The theory behind the occurrence of radio-femoral pressure difference is questionable. Pauca *et al*. [25] assumed that this pressure difference is caused by a decrease in vascular resistance of upper extremity vessels, whereas other studies proposed that peripheral vasoconstriction may be the underlying cause [26]. In the current study, SGB usage causes radial artery vasodilatation, thus decreasing this pressure difference, particularly at the end of CPB.

Limitations

This study had the following limitations. First, insufficient studies comparing the efficacy of SGB with pharmacological agents such as nitrates and calcium channel blockers in IMA diameter are available; second, placebo was not considered as a third arm in this study because during recruitment many patients were not eligible to participate in the study due to their critical medical condition or violation of the protocol; third, none of the patients were followed up using angiographic imaging after discharge home; fourth, the sample size was relatively small to provide definitive results, and also comparison with other sympathetic block techniques could be more beneficial; and finally, intraoperative flow devices such as pencil Doppler probe were not used to quantify the intraoperative flow, and it was assumed that the blood flow collected from cut end of IMA equalizes its blood flow when used as a conduit following the anastomosis.

Conclusion

The results of this study showed that SGB prevents the IMA spasm, increases IMA blood flow rate, and decreases the incidence of atrial fibrillations compared with intraluminal injection of verapamil-nitroglycerine combined with intravenous nicardipine.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 He GW. Arterial grafts for coronary surgery: vasospasm and patency rate. J Thorac Cardiovasc Surg 2001; 121:431–433.

2 Formica F, Ferro O, Brustia M, Corti F, Colagrande L, Bosissio E. Effects of papaverine and glyceryl nitrate-verapamil solution as topical and intraluminal vasodilators for internal thoracic artery. Ann Thorac Surg 2006; 81:120–124.

3 He GW, Yang CQ. Comparative study on calcium channel antagonists in the human radial artery: clinical implications. J Thorac Cardiovasc Surg 2000; 119:94–100.

4 Marples IL, Atkinson RE. Stellate ganglion block. Pain Rev 2001; 8:3–11.

5 Yildrim V, Akay HT, Bingol H, Bolcal C, Lyem H. Preemptive stellate ganglion block increases the patency of radial artery grafts in coronary artery bypass surgery. Acta Anaesth Scand 2007; 51:434–440.

6 Koyama S, Sato N, Nagashima K. Effects of right stellate ganglion block on the autonomic nervous function of the heart: a study using the head-up tilt test. Circ J 2002; 66:645–648.

7 Sarabu MR, McClung JA, Fass A, Reed GE. Early postoperative spasm in left internal mammary artery bypass grafts. Ann Thorac Surg 1987; 44:199–200.

8 Nili M, Stamler A, Sulkes J, Vidne BA. Preparation of the internal thoracic artery by vasodilator drugs: is it really necessary? A randomized double-blind placebo-controlled clinical study. Eur J Cardio-thorac Surg 1999; 16:560–563.

9 Pearson AA, Sauter RW. The internal thoracic (mammary) nerve. Thorax 1971; 26:354–356.

10 Cable DG, Caccitolo JA, Pearson PJ, O'Brien T, Mullany CJ. New approaches to prevention and treatment of radial artery graft vasospasm. Circulation 1998; 98(19 Suppl):II15–II21.

11 Moore R, Groves D, Hammond C, Leach A, Chester MR. Temporary sympathectomy in the treatment of chronic refractory angina. J Pain Symptom Manage 2005; 30:183–191.

12 Mahli A, Coskun D, Akcali DT. Aetiology of convulsions due to stellate ganglion block: a review and report of two cases. Eur J Anaesthesiol 2001; 19:376–380.

13 Yokoyama K, Sugiyama K. Hemodynamic effects of stellate ganglion block: analysis using a model of aortic input impedance. Can J Anaesth 2002; 49:887–888.

14 He GW. Arterial grafts: clinical classification and pharmacological management. Ann Cardiothorac Surg 2013; 2:507–518.

15 He GW, Rosenfeldt FL, Buxton BF, Angus JA. Reactivity of human isolated internal mammary artery to constrictor and dilator agents. Implications for treatment of internal mammary artery spasm. Circulation 1989; 80(3 Part 1):I141–I150.

16 Sasson L, Cohen AJ, Hauptman E, Schachner A. Effect of topical vasodilators on internal mammary arteries. Ann Thorac Surg 1995; 59:494–496.

17 Gopal D, Singh NG, Jagadeesh AM, Ture A, Thimmarayappa A. Comparison of left internal mammary artery diameter before and after left stellate ganglion block. Ann Card Anaesth 2013; 16:238–242.

18 Zabeeda D, Medalion B, Jackobshvilli S, Ezra S, Schachner A, Cohen AJ. Comparison of systemic vasodilators: effects on flow in internal mammary and radial arteries. Ann Thorac Surg 2001; 71:138–141.

19 Jadon A. Revalidation of a modified and safe approach of stellate ganglion block. Indian J Anaesth 2011; 55:52–56.

20 He GW, Shaw J, Hughes CF, Yang CQ, Thomson DS, McCaughan B, *et al.* Predominant alpha 1-adrenoceptor-mediated contraction in the human internal mammary artery. J Cardiovasc Pharmacol 1993; 21:256–263.

21 Leftheriotis D, Flevari P, Kossyvakis C, Katsaras D, Batistaki C, Arvaniti C, *et al.* Acute effects of unilateral temporary stellate ganglion block on human atrial electrophysiological properties and atrial fibrillation inducibility. Heart Rhythm 2016; 13:2111–2117.

22 Wei K, Feldmann REJr, Brascher AK, Benrath J. Ultrasound-guided stellate ganglion blocks combined with pharmacological and occupational therapy in Complex Regional Pain Syndrome (CRPS): a pilot case series ad interim. Pain Med 2014; 15:2120–2127.

23 He GW, Fan KY, Chiu SW, Chow WH. Injection of vasodilators into arterial grafts through cardiac catheter to relieve spasm. Ann Thorac Surg 2000; 69:625–628.

24 Kapoor MC, Khanna G. Stellate ganglion block in cardiac surgery. Ann Card Anaesth 2013; 16:242–244.

25 Pauca AL, Hudspeth AS, Wallenhaupt SL, Tucker WY, Kon ND, Mills SA, Cordell AR. Radial artery-to-aorta pressure difference after discontinuation of cardiopulmonary bypass. Anesthesiology 1989; 70:935–941.

26 Baba T, Goto T, Yoshitake A, Shibata Y. Radial artery diameter decreases with increased femoral to radial arterial pressure gradient during cardiopulmonary bypass. Anesth Analg 1997; 85:252–258.