STEAL PHENOMENON AFTER LUMBAR AND THORACIC SYMPATHETIC GANGLION BLOCKADE IN DOGS : THE INFLUENCE OF INTRAVASCULAR VOLUME

SHU MARUNAKA[1)], KEIJI HASHIZUME[2)], HIROAKI YAMAGAMI[3)], YOSHIHISA MIYATA[4)], and HITOSHI FURUYA[2)]

1) *Department of Anesthesiology, Haibara General Hospital*
2) *Department of Anesthesiology, Nara Medical University*
3) *Department of Anesthesiology, Kaiseikai Fujita Hospital*
4) *Department of Anesthesiology, Gojo Prefectural Hospital*

Received August 18, 2000

Abstract: The steal phenomenon between the bilateral sides following unilateral sympathetic denervation can be influenced by intravascular blood volume. We studied the changes in skin temperature as an indicator of this phenomenon induced by unilateral lumbar or thoracic sympathetic ganglion blockade in dogs under various hemodynamics. Each of 30 dogs in lumbar and thoracic experiments, which were divided into three groups according to mean right atrial pressure (RAP, mmHg) as hypovolemic (RAP$<$3 ; n=10), normovolemic (3$\leqq$RAP$\leqq$6 ; n=10) and hypervolemic (RAP$>$6 ; n=10), underwent unilateral high-frequency thermocoagulation in lumbar (L 5-L 7) or thoracic (Th 7-Th 11) sympathetic ganglia. Skin temperature at planta of both hindlimbs or bilateral costal arches was compared among three groups for 60 minutes following either blockade. Ipsilateral skin temperature rose in all groups ($p<0.05$). Contralateral skin temperature fell significantly only in the hypovolemic and the normovolemic groups ($p<0.05$), but not in the hypervolemic group. After lumbar sympathetic blockade, the changes is the contralateral skin temperature for 60 minutes, expressed as a percentage of the respective control value, were significantly larger ($p<0.05$) in the hypovolemic (-6.4 ± 1.8 %) and the normovolemic (-6.0 ± 2.2 %) groups than that in the hypervolemic group ($+0.1\pm1.7$ %). After thoracic sympathetic blockade, this percentage change was significantly different ($p<0.05$) among the hypovolemic (-1.2 ± 0.7 %), the normovolemic (-0.7 ± 0.6 %) and the hypervolemic ($+0.0\pm0.4$ %) groups.

We conclude that the steal phenomenon may be influenced by intravascular volume. Therefore, it is necessary to sufficiently understand the patient's systemic hemodynamics or peripheral circulation in performing unilateral sympathetic ganglion blockade. Furthermore, a pretreatment such as a preoperative volume loading can be beneficial, especially for the hypovolemic patient who has bilateral vascular disorders.

(奈医誌. J. Nara Med. Ass. **51**, 343～353, 2000)

Key words: steal phenomenon, skin temperature, sympathetic ganglion blockade, intravascular volume, dog

INTRODUCTION

Percutaneous sympathetic ganglion blockade is less invasive than surgical procedures such as vascular reconstruction or sympathectomy and has been used widely to treat vascular occlusive disorders, reflex sympathetic dystrophy, hyperidrosis, herpetic or post-herpetic pain, and cancer pain[1-4]. High-frequency thermocoagulation, as a nerve-block technique, has additional advantages including more selective nerve blockade and a shorter postoperative period of immobilization compared to chemical nerve blockade. This procedure has recently been applied to sympathetic ganglion blockade[5-8].

The "steal" phenomenon is well-known to be peripheral circulatory changes which increase blood-volume in one part of the body with a corresponding simultaneous blood-volume decrease in another part without any alteration in total blood volume[9]. This diversion of blood does not always result in the most desirable pattern of blood distribution[10] and unfavorable consequences have been reported following surgical procedures such as sympathectomy or vascular reconstruction[11-12]. Unilateral sympathetic ganglion blockade can also result in the redistribution of blood from the unblocked side to the blocked side, resulting in new or worsened symptoms on the unblocked side[13]. Moreover, the concept of this phenomenon assumes that the total blood volume is constant. A change in total blood volume may add complexity to this redistribution phenomenon.

In this study, we investigate whether unilateral sympathetic ganglion blockade can cause the "steal" phenomenon and whether this phenomenon can be influenced by altering the intravascular volume. To assess this phenomenon, we selected the skin temperature, which has been thought to be one of the useful indices of skin blood flow[1,14-16]. The changes in bilateral skin temperatures caused by unilateral lumbar or thoracic sympathetic ganglion blockade with high-frequency thermocoagulation in dogs were studied under various right atrial pressures.

METHODS

The study was approved by the Animal Care Committee at the authors' institution. Experiments were performed on 60 healthy mongrel dogs of either sex (weight, 8.5-22 kg). All dogs fasted for nine hours before the start of the experiment.

After intramuscular injection of ketamine hydrochloride (2-5 mg/kg), the dogs were fixed in supine position on a heating pad and an intravenous line was inserted into their anterior limbs. After the induction of anesthesia with intravenous bolus injection of 20-25 mg/kg pentobarbital sodium and the paralysis with vecuronium bromide (0.4 mg/kg bolus injection, followed by 0.1 mg/kg/hr), the trachea was intubated and the lungs were mechanically ventilated with a volume-controlled ventilator (Harvard Respirator, South Natick, MA) to maintain normocapnia. Normocapnia was confirmed by the measurement of arterial blood $PaCO_2$ with a blood gas analyzer (ABL 2 ; Radiometer, Copenhagen, Denmark) and by the continuous measurement of end-tidal carbon dioxide with a carbon dioxide analyzer (HP 14360 A Carbon Dioxide Transducer ; Hewlett Packard, Andover, MA). Anesthesia was maintained by continuous intravenous infusion of fentanyl and midazolam at the rate of 2.0-2.5 μg/kg/hr and 0.05 mg/kg/hr, respectively. Ringer's lactate solution was infused at a rate of 10 mL/kg/hr. A catheter was inserted into the right common carotid artery to monitor the mean arterial pressure (MAP) and to sample blood. A pulmonary arterial thermodilution catheter (Baxter Edwards Critical-Care Division, Irvine, CA) was inserted via the right external jugular vein to monitor the mean pulmonary artery pressure (PAP) and the pulmonary artery wedge pressure (PAWP). A catheter was inserted into the right atrium via the right external jugular vein to monitor the mean right atrial pressure (RAP). These three pressure catheters were connected to a multichannel monitor (7835 A 4, Hewlett Packard, MA) using transducers.

Lumbar sympathetic ganglion blockade and skin temperature measurement (n=30)

After a midline abdominal incision, the left lumbar sympathetic trunks and ganglia were exposed. Left lumbar sympathetic ganglion blockade was performed at the level of L 5-L 7 vertebrae by thermocoagulation at 90℃ for 120 seconds using an insulated needle-electrode (Type SMK Sluijter-Mehta cannula, Radionics, Burlington, MA) with a 4 mm active tip and high-frequency thermocoagulation equipment (Model RFG-3 B Lesion Generator System, Radionics, Burlington, MA). By subcutaneously inserting a needle probe (PD-N 031, Terumo, Japan) connected with an electronical thermistor temperature monitor (Terumo-Finer model CTM 303, Terumo, Japan), the temperature accuracy of which is ±0.1℃, skin temperature was measured at planta of both hindlimbs, which are innervated by the lower lumbar sympathetic nerves[17].

Thoracic sympathetic ganglion blockade and skin temperature measurement (n=30)

After a right thoractomy at the fifth intercostal space, the right thoracic sympathetic trunks and ganglia were exposed. In the same way as the lumbar experiment, right thoracic sympathetic ganglion blockade was performed at the level of the Th 7-Th 11 vertebrae, and skin temperature was measured on bilateral costal arches, which are innervated by the lower thoracic sympathetic nerves[18].

After stabilization of hemodynamics under general anesthesia, all hemodynamic variables and skin temperatures on both sides were measured as control values. Each dog was assigned to a group of 10 according to its control value of RAP (mmHg): hypovolemic (Hypo group), RAP<3 ; normovolemic (Normo group), 3≦RAP≦6 ; hypervolemic (Hyper group), RAP>6[19]. The RAP of all dogs was less than 6 mmHg in our regular experimental protocol (a fast for nine hours before the start of experiment and an infusion of lactate ringer solution at a rate of 10 ml/kg/hr). Thus, several dogs received extra volume load (hydroxyethyl-starch solution, 10-20 ml/kg) previous to the measurement of control value, and these dogs were assigned to the Hyper group after a confirmation that their RAP was kept above 6 mmHg at the measurement of control value.

Immediately after exposure of the sympathetic trunks and ganglia (pre-blockade), and 5, 20, and 60 minutes after sympathetic ganglion blockade, hemodynamic variables and skin temperatures on both sides were remeasured and compared with each control value. A comparison of skin temperatures between bilateral sides was made at each point within each group. The change in contralateral skin temperature from control up to 60 minutes after sympathetic ganglion blockade in each group was expressed as a percentage of each control value and these percentage changes were compared among the three groups. During the experiment, room temperature was kept constant and body temperature of the dog was was kept constant with a heating pad to avoid the influence of ambient temperatume. Additionally, the skin temperature of an anterior limb and the rectal temperature was monitored to confirm constant peripheral and core temperatures. After the experiment, the dogs were killed by intravenous injection of potassium chloride under deep anesthesia and death was confirmed from the electrocardiogram, artery pressure wave form, and signs of post-mortem rigidity.

Data are expressed as mean±SD. Between-group differences of hemodynamic variables and percentage changes of contralateral skin temperatures were analyzed by one-way analysis of variance. When the analysis of variance detected a significant difference, *post hoc* comparisons were performed using Fisher's protected least significant difference test. Within-group differences between bilateral skin temperatures, and over time changes of hemodynamic variables or skin temperatures relative to each control values were analyzed using a paired Student's t test. The level of statistical significance was defined as $P<0.05$.

RESULTS

Study of lumbar sympathetic ganglion blockade

There were no significant between-group differences in control values of the heart rate (HR), and MAP among the three groups (Table 1). Control values of RAP were significantly different among three groups, while control values of PAP were significantly different only between the Hypo and the Hyper groups. Control values of PAWP in the Hyper group were significantly different from those in the other two groups. All hemodynamic variables and their between-group differences showed almost no significant changes during the experiment.

Table 2 shows the skin temperature at planta of both hindlimbs before and after unilateral lumbar sympathetic ganglion blockade in the three groups. Initial ipsilateral and contralateral skin temperatures were similar to each other in all groups. Ipsilateral skin temperatures rose 5 minutes after the blockade and these rises continued until 60 minutes after the blockade in all

Table 1. Hemodynamic variables before and after unilateral high-frequency thermocoagulation lumbar sympathetic ganglion blockade

			Time after blockade		
	Control	Pre-blockade	5 min.	20 min.	60min.
HR(/min)					
Hypo group	139±19	137±19	139±17	138±20	137±20
Normo group	137±23	138±26	138±25	136±26	136±25
Hyper group	136±18	134±19	135±19	135±17	134±17
MAP(mmHg)					
Hypo group	113±15	114±14	114±14	112±13	114±14
Normo group	116±13	113±14	117±13	115±11	116±11
Hyper group	122±13	124±14	124±13	125±13	122±12
RAP(mmHg)					
Hypo group	1±1#	2±1#	1±1#	1±1#	2±1#
Normo group	5±1*	5±1*	5±1*	5±1*	5±1*
Hyper group	8±1*#	8±1*#	8±1*#	8±1*#	8±1*#
PAP(mmHg)					
Hypo group	16±3	16±3	16±3	17±3	17±3
Normo group	18±2	18±2	18±2	17±2	18±1
Hyper group	20±4*	20±3*	21±3*#	20±3*	20±3*
PAWP(mmHg)					
Hypo group	9±1	8±2	9±1	8±2	9±2
Normo group	10±2	10±2*	10±2	10±2	10±2
Hyper group	12±2*#	13±3*#	12±3*#	12±2*#	12±2*#

Values are mean±SD. HR=heart rate ; MAP=mean arterial pressure ; RAP=mean right atrial pressure ; PAP=mean pulmonary artery pressure ; PAWP=pulmonary artery wedge pressure.
* ; P<0.05 vs Hypo group. # ; P<0.05 vs Normo group.

three groups. In both the Hypo and the Normo groups, contralateral skin temperatures fell 5 minutes after the blockade and these falls continued until 60 minutes after the blockade; however contralateral skin temperature in the Hyper group showed no significant change. At 5, 20, and 60 minutes after the blockade, there were significant differences between ipsilateral and contralateral skin temperatures in each group. The changes in the contralateral skin

Table 2. Skin temperature at planta of both hindimbs before and after unilateral high-frequency thermocoagulation lumbar sympathetic ganglion blockade (℃)

	Control	Pre-blockade	Time after blockade 5 min.	20 min.	60min.
Hypo group					
Ipsilateral	32.0±2.1	32.0±2.1	34.4±1.8*#	34.5±1.8*#	34.5±1.7*#
Contralateral	31.9±2.2	32.0±2.1	30.2±2.1*	29.8±1.9*	29.9±1.9*
Normo group					
Ipsilateral	32.1±1.8	32.2±1.7	34.5±1.5*#	34.6±1.3*#	34.7±1.4*#
Contralateral	32.1±1.8	32.2±1.7	30.3±1.8*	30.2±1.9*	30.2±1.9*
Hyper group					
Ipsilateral	32.1±1.9	32.1±1.9	34.8±1.4*#	34.8±1.4*#	34.9±1.4*#
Contralateral	32.1±2.1	32.1±2.1	32.2±2.1	32.2±2.1	32.2±2.2

Values are mean±SD.
Ipsilateral=the side in which sympathetic ganglion blockade was performed; Contralateral=the opposite side of Ipsilateral.
* ; $P<0.05$ vs Control within each group. # ; $P<0.05$ vs Contralateral within each group.

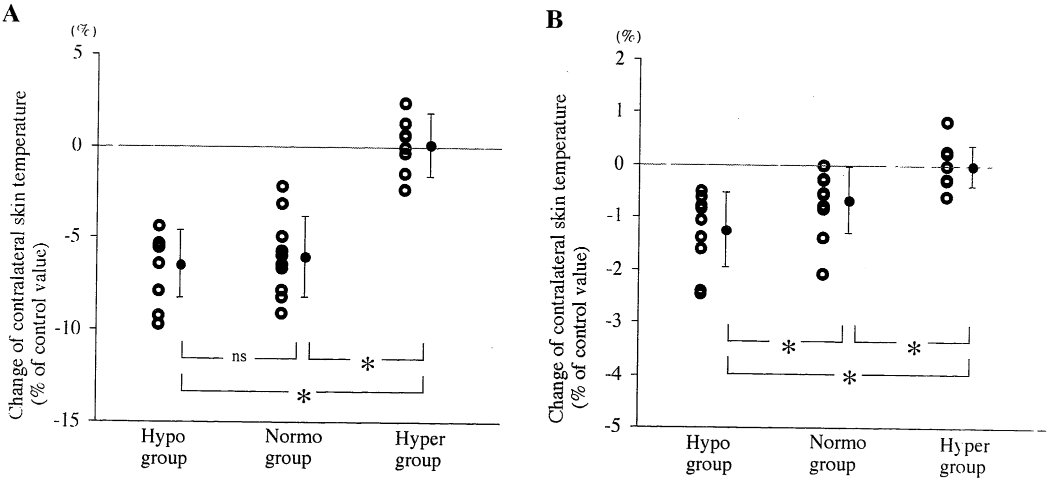

Fig. 1. A; The change of skin temperature at planta of contralateral hindlimb from control to 60 minutes after unilateral high-frequency thermocoagulation lumbar (L5-L7) sympathetic ganglion blockade, expressed as a percentage of each control tempeture in three groups.
B; the same percentage change of skin temperature on contralateral costal arch after unilateral high-frequency thermocoagulation thoracic (Th7-Th11) sympathetic ganglion blockade in three groups.
Open circles; individual values, filled circles; average of individual values in each group.
ns; no significant difference between two groups.
* ; $P<0.05$ significantly different between two groups.

temperature from control up to 60 minutes after the blockade, expressed as a percentage of the respective control value, were similar in the Hypo group (−6.4±1.8%) and in the Normo group (−6.0±2.2%); in contrast, this percent change was only +0.1±1.7% in the Hyper group, significantly smaller than those for other two groups (Fig. 1).

Study of thoracic sympathetic ganglion blockade

There were no significant between-group differences in control values of HR, MAP, and PAP (Table 3). Control values of RAP were significantly different among the three groups, while

Table 3. Hemodynamic variables before and after unilateral high-frequency thermocoagulation thoracic sympathetic ganglion blockade

	Control	Pre-blockade	Time after blockade 5 min.	20 min.	60min.
HR(/min)					
Hypo group	132±38	133±36	133±39	137±36	136±34
Normo group	150±26	152±28	156±32	154±29	151±30
Hyper group	141±32	144±30	146±31	144±33	144±30
MAP(mmHg)					
Hypo group	114±15	113±16	112±17	112±16	112±16
Normo group	119±24	118±21	120±22	118±24	118±22
Hyper group	126±9	123±10	122±12	123±8	124±10
RAP(mmHg)					
Hypo group	1±1#	1±1#	1±1#	1±1#	1±1#
Normo group	4±1*	4±1*	4±1*	4±0*	4±1*
Hyper group	7±1*#	7±1*#	7±1*#	7±1*#	7±1*#
PAP(mmHg)					
Hypo group	16±4	16±4	16±4	15±4	16±4
Normo group	18±5	19±6	20±6	19±5	19±6
Hyper group	21±6	20±7	20±7	20±8	20±7
PAWP(mmHg)					
Hypo group	8±4	8±3	7±3	8±3	7±3
Normo group	10±3	10±3	10±3	10±4	10±3
Hyper group	12±3*	12±2*	11±3*	11±3*	11±3*

Values are mean±SD. HR=heart rate; MAP=mean arterial pressure; RAP=mean right atrial pressure; PAP=mean pulmonary artery pressure; PAWP=pulmonary artery wedge pressure.
*; $P<0.05$ vs Hypo group. #; $P<0.05$ vs Normo group.

Table 4. Skin temperature on bilateral costal arches before and after unilateral high-frequency thermocoagulation thoracic sympathetic ganglion blockade (℃)

	Control	Pre-blockade	Time after blockade 5 min.	20 min.	60min.
Hypo group					
Ipsilateral	37.2±1.5	37.2±1.5	37.5±1.5*#	37.4±1.5*#	37.5±1.5*#
Contralateral	37.1±1.5	37.1±1.5	36.7±1.5*	36.7±1.5*	36.7±1.5*
Normo group					
Ipsilateral	36.5±1.6	36.5±1.6	36.7±1.6*#	36.6±1.6*#	36.6±1.6*#
Contralateral	36.5±1.6	36.5±1.6	36.3±1.6*	36.2±1.7*	36.2±1.7*
Hyper group					
Ipsilateral	37.3±1.8	37.3±1.8	37.6±1.8*#	37.5±1.8*#	37.6±1.7*#
Contralateral	37.2±1.7	37.2±1.7	37.2±1.7	37.2±1.8	37.2±1.8

Values are mean±SD.
Ipsilateral=the side in which sympathetic ganglion blockade was performed; Contralateral=the opposite side of Ipsilateral.
*; $P<0.05$ vs Control within each group. #; $P<0.05$ vs Contralateral within each group.

control values of PAWP were significantly different only between the Hypo and the Hyper groups. Hemodynamic variables and their between-group differences showed almost no significant change during the experiment.

Table 4 shows the skin temperature on bilateral costal arches before and after unilateral thoracic sympathetic ganglion blockade in the three groups. Initial ipsilateral and contralateral skin temperatures were similar to each other in all groups. Ipsilateral skin temperature rose 5 minutes after the blockade and these rises continued until 60 minutes after the blockade in all three groups. In both the Hypo and the Normo groups, contralateral skin temperature fell 5 minutes after the blockade and these falls continued until 60 minutes after the blockade; however, contralateral skin temperature in the Hyper group showed no significant change. At each time after the blockade, there were significant differences between bilateral skin temperatures in each group. The percentage changes in the contralateral skin temperature from control up to 60 minutes after the blockade were significantly different among the Hypo (−1.2 ±0.7%), the Normo (−0.7±0.6%) and the Hyper (+0.0±0.4%) groups (Fig. 1).

During both experiments, the skin temperature of anterior limb and the rectal temperature showed no significant change in all groups (Table 5).

Table 5. Skin temperature of anterior limb and rectal temperature before and after unilateral high-frequency thermocoagulation lumbar or thoracic sympathetic ganglion blockade (℃)

Lumbar study

	Control	Pre-blockade	Time after blockade		
			5 min.	20 min.	60min.
PT					
Hypo group	32.7±1.3	32.8±1.3	32.8±1.4	32.8±1.4	32.8±1.3
Normo group	32.8±1.4	32.8±1.5	32.9±1.3	32.8±1.4	32.8±1.3
Hyper group	32.8±1.3	32.8±1.2	32.8±1.4	32.8±1.4	32.8±1.3
CT					
Hypo group	36.8±0.7	36.8±0.7	36.8±0.7	36.8±0.7	36.8±0.7
Normo group	36.8±0.5	36.8±0.6	36.8±0.4	36.8±0.6	36.8±0.5
Hyper group	36.8±0.6	36.9±0.5	36.8±0.7	36.8±0.5	36.8±0.6

Thoracic study

	Control	Pre-blockade	Time after blockade		
			5 min.	20 min.	60min.
PT					
Hypo group	33.4±1.4	33.3±1.5	33.3±1.5	33.3±1.6	33.3±1.5
Normo group	33.2±1.5	33.2±1.5	33.2±1.6	33.2±1.5	33.2±1.5
Hyper group	33.3±1.7	33.3±1.8	33.3±1.8	33.3±1.8	33.3±1.7
CT					
Hypo group	37.3±1.5	37.3±1.5	37.3±1.5	37.3±1.5	37.3±1.5
Normo group	36.6±1.6	36.7±1.6	36.6±1.5	36.7±1.5	36.6±1.5
Hyper group	37.4±1.7	37.4±1.7	37.3±1.6	37.3±1.7	37.3±1.6

Values are mean±SD.

PT=the skin temperature of anterior limb, CT=the rectal temperature, Lumbar study=the study of lumbar sympathetic ganglion blockade, Thoracic study=the study of thoracic sympathetic ganglion blockade

DISCUSSION

In this study, we monitored the skin temperature of anterior limb or the rectal temperature and confirmed that there was no change of peripheral or core temperature throughout the experiment. Therefore, the "steal" phenomenon can be estimated by measuring skin temperature, which is thought to reflect skin blood flow in constant circumstances[1,14-16].

Our results showed the rise of ipsilateral skin temperature in all groups and the fall of contralateral skin temperature only in the Hypo and the Normo groups, but not in the Hyper group after unilateral lumbar or thoracic sympathetic ganglion blockade. These observations suggest that unilateral sympathetic ganglion blockade increasing ipsilateral skin blood flow, in turn, causes a decrease of the contralateral skin blood flow under hypovolemic or normovolemic states but not under the hypervolemic state.

The "steal" phenomenon is a concept suggested by DeBakey and defined as a well-regulated mechanism of the peripheral circulation ; an effective utilization of limited total blood volume[9]. Because of the unchanged total blood flow, systemic or dilatation of a distal vascular bed may cause blood diversion away from other tissue and this diversion is not always beneficial[10]. It is believed that lumbar sympathectomy causes the following unfavorable phenomena of blood distribution: 1) decreased capillary perfusion caused by opening of precapillary anastomoses ; 2) decreased blood flow to muscles caused by increasing cutaneous blood flow ; 3) decreased blood flow in the contralateral limb resulting from increasing blood flow in the limb which has undergone sympathectomy[1,20-21]. We actually observed the 3 rd phenomenon after unilateral sympathetic ganglion blockade with high-frequency thermocoagulation in the present study. May et al. also observed a similar "steal" phenomenon after unilateral sympathetic ganglionectomy in dogs by measuring bilateral iliac blood flows with an electromagnetic flow meter[22].

As the "steal" phenomenon is proposed under the constant intravascular volume, this phenomenon may become more complex if intravascular volume changes. However, there are no reports which investigate the relationship between this phenomenon and intravascular volume, to the best of our knowledge. Our result showing that the fall of contralateral skin temperature found in the other two groups was not observed in the Hyper group suggest that the intravascular volume may contribute to this phenomenon. In case of intravascular volume being normal or less than normal, a unilateral sympathetic blockade causes a blood diversion from the contralateral intact side to the blocked side, but this diversion can be minimized with adequate correction of intravascular volume.

Underlying mechanisms for the "steal" phenomenon include imbalance of resistances in blood vessels of both sides caused by dilation of ipsilateral blood vessel and/or contralateral compensatory vasoconstriction. In accordance with the inverse relationship between resistance and flow, the ipsilateral post-denervated vessel which has relatively low resistance receives increased blood flow from the contralateral vessel which has a relatively high resistance[1,12]. The increase of blood flow caused by a vasodilation in one part of the body could bring about the decrease of blood flow in all parts of the body except the vasodilated part. However, we found no change in the skin temperature of anterior limb and the rectal temperature after lumbar or lower thoracic sympathetic ganglion blockades, indicating unchanged blood flow in these regions. This result may have been due to the localized sympathetic denervation in this study, which did not obviously cause a generalized decrease of blood flow in the body. However, a more widespread sympathetic ganglion blockade can cause a decrease of blood flow in not only the contralateral region but also another region of the body. The change in the skin temperature on both sides after thoracic blockade was smaller than that after lumbar blockade in our study. It is explained that the thoracic area has a greater redundancy of sympathetic innervation and a more complex form of blood-distribution than the lumbar area.

The peripheral vasodilation produced by sympathetic ganglion blockade could result in relative hypovolemia that might influence systemic hemodynamics. There is a possibility that RAP and other filling pressures would fall, particularly when an extensive dilation of the splanchnic vasculature is caused by sympathetic ganglion blockade. However, we found no change in any of these values after sympathetic ganglion blockade. This may have been due to the limited extent of the sympathetic denervation in this study, which did not bring about sufficient vasodilation and resultant pooling of blood to affect systemic hemodynamics.

Sympathetic ganglion blockade has been generally applied to vascular occlusive disorders such as chronic arterial occlusive disease or Raynaud's disease, reflex sympathetic dystrophy, hyperidrosis, herpetic or post-hespetic pain, and cancer pain[1-4]. High-frequency thermocoagulation has the advantages of more selective and localized nerve block through adjustment of tip-temperature or coagulation time, and shorter postoperative immobilization periods than chemical nerve block using neurolytics or local anesthetics. Thus, this method has been used not only for the nerve block of nerve roots, posteriomedial branches, dorsal root entry zones, trigeminal ganglia, and spinal cord[23-27], buo also for thoracic[5-6] or lumbar[7-8] sympathetic ganglion blockade. Since sympathetic ganglion blockade including high-frequency thermocoagulation is less invasive than surgical procedures such as lumbar sympathectomy or vascular reconstruction, it would be performed more often in high-age and high-risk patients. Although there are fewer clinical reports regarding the "steal" phenomenon after sympathetic ganglion bkockade than after the surgical procedures[13,28], we should recognize this phenomenon as a serious complication of this blockade.

When we would perform unilateral sympathetic ganglion blockade, it is important to give attention to the possibility that the "steal" phenomenon may cause or worsen ischemic symptoms on the unblocked side, especially in a patient with bilateral vascular disorder who has the risk of dehydration. It is possible to prevent this phenomenon by sufficient volume loading in the preoperative period. Treatment decisions should be made carefully based on the overall evaluation of angiographic findings (such as location or degree of obstruction, collateral flow, and distal flow), anticipated remaining sympathetic function and severity of the symptoms. A test of sympathetic ganglion blockade with local anesthetics can be useful to determine whether blood flow of the blocked side can be increased by sympathetic denervation and whether the symptoms of the unblocked side can be worsened by the "steal" phenomenon.

Since the "steal" phenomenon between blocked and unblocked sides after unilateral sympathetic ganglion blockade may be affected by intravascular volume, the block should be performed after the patient's intravascular volume has been completely examined and the patient should be hydrated if necessary.

(Acknowledgment. The authors thank Professor M. Takagi, Department of Physiology, Nara

Medical University, for reviewing the manuscript.)

REFERENCES

1) **Lofstrom, J. B.** and **Cousins, M. J.**: Neural blockade in clinical anesthesia and management of pain (Cousins, M. J., eds.). 2 nd ed., J. B. Lippincott, Philadelphia, 461-500, 1988.
2) **Cotton, L. T.** and **Cross, F. W.**: Lumbar sympathectomy for arterial disease. Br. J. Surg. **72**: 678-683, 1985.
3) **Cousins, M. J., Reeve, T. S., Glynn, C. J., Walsh, J. A.** and **Cherry, D. A.**: Neurolytic lumbar sympathetic blockade: duration of denervation and relief of rest pain. Anaesth. Intens. Care **7**: 121-135, 1979.
4) **Ohseto, K.**: Efficacy of thoracic sympathetic ganglion block and prediction of complications: clinical evaluation of the anterior paratracheal and posterior paravertebral approaches in 234 patients. J. Anesth. **6**: 316-331, 1992.
5) **Wilkinson, H. A.**: Percutaneous radiofrequency upper thoracic sympathectomy: a new technique. Neurosurgery **15**: 811-814, 1984.
6) **Chuang, K. S., Liou, N. H.** and **Liu, J. C.**: New stereotactic technique for percutaneous thermocoagulation upper thoracic ganglionectomy in cases of palmar hyperhidrosis. Neurosurgery **22**: 600-604, 1988.
7) **Kantha, K. S.**: Techniques of neurolysis (Radiofrequency percutaneous lumbar sympathectomy: technique and review of indications) (Racz G. B. eds.). Kluwer Academic Publishers, Boston, 171-183, 1989.
8) **Arter, O. E.** and **Racz, G. B.**: Pain management of the oncologic patient. Seminars in Surgical Oncology **6**: 162-172, 1990.
9) **DeBakey, M. E., Burch, G., Ray, T.** and **Ochsner, A.**: The "borrowing-lending" hemodynamic phenomenon (hemometakinesia) and its therapeutic application in peripheral vascular disturbances. Ann. Surg. **126**: 850-865, 1947.
10) **Hyman, C.** and **Winsor, T.**: Blood flow redistribution in the human extremity: the diversion phenomenon. Am. J. Cardiol. **4**: 566-571, 1959.
11) **Collins, G. J., Rich, N. M., Clagett, G. P., Salander, J. M.** and **Spebar, M. J.**: Clinical results of lumbar sympathectomy. Am. Surg. **47**: 31-35, 1981.
12) **Baron, H. C., Hiesiger, E.** and **Sabri, M.**: Undesirable effects of hemometakinesia induced by vascular reconstruction. Surg. Gynecol. Obstet. **148**: 534-538, 1979.
13) **Irazuzta, J. E., Berde, C. B.** and **Sethna, N. F.**: Laser doppler measurements of skin blood flow before, during, and after lumbar sympathetic blockade in children and young adults with reflex sympathetic dystrophy syndrome. J. Clin. Monit. **8**: 16-19, 1992.
14) **Nilsson, A. L.**: Blood flow, temperature, and heat loss of skin exposed to local radiative and convective cooling. J. Invest. Dermatol. **88**: 586-593, 1987.
15) **Bell, C., Janig, W., Kummel, H.** and **Xu, H.**: Differentiation of vasodilator and sudomotor responses in the cat paw pad to preganglionic sympathetic stimulation. J. Physiol. **364**: 93-104, 1985.
16) **Swain, I. D.** and **Grant, L. J.**: Methods of measuring skin blood flow. Phys. Med. Biol. **34**: 151-175, 1989.
17) **Hiratani, K.**: The study of lumbar sympathectomy, about the region of ganglionectomy in particular. The Autonomic Nervous System **25**: 24-33, 1988. (Abstract English)
18) **Yamagami, H.**: The hemodynamic effect of thoracic sympathetic ganglion blockade in the anesthetized adult mongrel dogs. Jpn. J. Anethesiol. **43**: 361-368, 1994. (Abstract English)
19) **Howard, R. J., Stopps, T. P., Moe, G. W.** and **Armstrong, P. W.**: A new method for hemodynamic and echocardiographic assessment of conscious dogs: comparison with thiopental-morphine anaesthesia. Clinical and Investigative Medicine **13**: 6-10, 1990.
20) **Stright, V. D.**: 50 years of lumbar sympathectomy (hemometakinesia). J. Cardiovas. Surg. **20**: 324-325, 1979.

21) **Cronenwett, J. L., Zelenock, G. B., Whitehouse, W. M., Stanley, J. C.** and **Lindenauer, S. M.**: The effect of sympathetic innervation on canine muscle and skin blood flow. Arch. Surg. **118**: 420-424, 1983.

22) **May, A. G., DeWeese, J. A.** and **Rob, C. G.**: Effect of sympathectomy on blood flow in arterial stenosis. Ann. Surg. **158**: 182-188, 1963.

23) **Uematsu, S., Udvarhelyi, G. B., Benson, D. W.** and **Siebens, A. A.**: Percutaneous radiofrequency rhizotomy. Surg. Neurol. **2**: 319-325, 1974.

24) **Bogduk, N.** and **Long, D. M.**: Percutaneous lumbar medial branch neurotomy: a modification of facet denervation. Spine. **5**: 193-200, 1980.

25) **Cosman, E. R., Nashold, B. S.** and **Ovelman-Levitt, J.**: Theoretical aspects of radiofrequency lesions in the dorsal root entry zone. Neurosurgery **15**: 945-950, 1984.

26) **Pawl, R. P.**: Percutaneous radiofrequency electrocoagulation in the control of chronic pain. Surg. Clin. North. Am. **55**: 167-179, 1975.

27) **Mullan, S.**: Percutaneous cordotomy. J. Neurosurg **35**: 360-366, 1971.

28) **Uhrenholdt, A., Dam, W. H., Larsen, O. A.** and **Lassen, N. A.**: Paradoxical effect on peripheral blood flow after sympathetic blockades in patients with gangrene due to arteriosclerosis obliterans. Vasc. Surg. **5**: 154-163, 1971.