

# Venous Hemodynamic Changes in the Surgical Treatment of Primary Varicose Vein of the Lower Limbs

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Venous hemodynamic changes after the surgery of primary varicose veins were evaluated. (Materials and methods) We retrospectively analyzed 1,211 patients (1,407 limbs) who underwent surgery for primary varicose veins from 1994 to 2002. The venous hemodynamics were evaluated using air-plethysmography (APG) preoperatively and one month post-operatively in the viewpoints of ambulatory venous pressure (AVP), venous volume (VV), venous filling index (VFI), and ejection fraction (EF). (Results) The surgical modalities included 958 cases of greater saphenous vein high ligation (GSV HL) and stripping with varicosectomy (VS), 222 cases of short saphenous vein (SSV) HL and VS, 143 cases of external banding valvuloplasty of GSV and VS, and 44 cases using VNUS<sup>®</sup> and VS. The reduction rate of VV was  $20.9 \pm 14.1\%$  in the GSV stripping group,  $12.0 \pm 14.7\%$  in the GSV valvuloplasty group,  $18.3 \pm 16.1\%$  in the VNUS<sup>®</sup> group, and  $20.6 \pm 15.9\%$  in the SSV group. The reduction rate of VFI was  $63.6 \pm 20.7\%$  in the GSV stripping group,  $38.8 \pm 40.9\%$  in the GSV valvuloplasty group,  $60.1 \pm 23.9\%$  in the VNUS<sup>®</sup> group, and  $37.6 \pm 30.2\%$  in the SSV group. The increasing rate of EF was  $25.0 \pm 28.2\%$  in the GSV stripping group,  $21.0 \pm 30.0\%$  in the GSV valvuloplasty group,  $29.4 \pm 31.9\%$  in the VNUS<sup>®</sup> group, and  $30.0 \pm 36.5\%$  in the SSV group. The reduction rate of AVP was  $25.4 \pm 32.2\%$  in the GSV stripping group,  $-6.1 \pm 58.1\%$  in the GSV valvuloplasty group,  $28.4 \pm 38.5\%$  in the VNUS<sup>®</sup> group, and  $14.1 \pm 49.0\%$  in the SSV group. All of the patients showed improvements in venous hemodynamics by showing a decrease in VV, VFI, AVP, and an increase in EF. However, there was no difference in the change of venous hemodynamics according to the type of surgery.

**Key Words:** Varicose vein, hemodynamics, air-plethysmography

## INTRODUCTION

Saphenous veins of the lower limbs have valves that prevent regurgitation of venous flow. It has been suggested that varicose veins may develop from valve failure caused by increased venous pressure. This results from the lack of valves above the saphenofemoral junction, but there is no precise information about the cause of valvular insufficiency. Treatments for primary varicose veins include non-operative management, compressive therapy, sclerotherapy, and operative management, but operative management is mainly used for curative purposes. High ligation of the saphenous vein at the junction of the deep vein and stripping were performed to remove the main cause of primary varicose veins. Recently, many methods have been adapted to block the reflux through the saphenous vein. However, there are no published results on comparative data between traditional methods and recently adapted methods. In the meantime, the development of air-plethysmography (APG) enabled us to evaluate venous hemodynamics noninvasively. In this study, we compared the venous hemodynamic changes before and after the operation.

## MATERIALS AND METHODS

We retrospectively analyzed 1,211 patients (1,407 limbs) who underwent surgery for primary varicose veins from September 1994 to December 2002 in our hospital. According to the CEAP classification, 1,386 limbs were C2 (varicose veins), 21 limbs were C2,4 (varicose veins, skin changes), 1,407 limbs were EP (primary), PR (reflux), and

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AS (superficial). The operative managements included high ligation, stripping of the greater saphenous vein and varicosectomy; high ligation of the short saphenous vein and varicosectomy; external banding valvuloplasty of the greater saphenous vein and varicosectomy; Linton's operation; ligation of the greater saphenous venous branch and varicosectomy; obliteration of the greater saphenous vein using VNUS<sup>®</sup> system (VNUS Medical Technologies Inc., San Jose, CA, USA) and varicosectomy. The venous hemodynamics of the limbs were preoperatively evaluated using air-plethysmography (APG) and were also evaluated one month postoperatively in a viewpoint of ambulatory venous pressure (AVP), venous volume (VV), venous filling index (VFI), and ejection fraction (EF). Statistical analysis was carried into effect using the student t-test using the SPSS statistical package (version 10.0, SPSS Inc., IL, USA).

## RESULTS

### Age/sex distribution

The total of 1,211 patients consisted of 368 males (30.3%) and 843 females (69.7%). Male to female ratio was 1: 2.3. The mean age was  $46.9 \pm 10.3$  years. The prevalent age was 40 to 49-years (male 27.1%, female 38.4%, total 35.0%) (Table 1).

### Durations of illness

The duration from the first development of signs and symptoms to their primary treatment was 6 to 10 years in 398 cases (32.9%) and 11 to 20 years in 345 cases (28.5%) (Table 2).

**Table 2.** Duration of Illness

Durations (years)	Cases (%)
< 5	261 (21.6)
6-10	398 (32.9)
11-20	345 (28.5)
21-30	149 (12.3)
> 31	58 (4.8)
Total	1,211 (100)

### Types of operation

High ligation and stripping of the greater saphenous vein and varicosectomy was carried out in 958 cases (68.0%). Of the 958 cases, 920 cases (65.4%), underwent high ligation of the greater saphenous vein and varicosectomy but stripping was performed only above the knee. In 38 cases (2.7%), high ligation and total stripping of the greater saphenous vein and varicosectomy was performed. Among these cases, 156 cases of varicosectomy were done using the Trivex<sup>TM</sup> system (Smith and Nephew Inc., Andover, MA, USA). High ligation of the short saphenous vein and varicosectomy was conducted in 222 cases (15.8%). External banding valvuloplasty of the greater saphenous vein and varicosectomy was conducted in 143 cases (10.2%). Linton's operation was conducted in 21 cases (1.5%), ligation of the greater saphenous venous branch and varicosectomy in 19 cases (1.4%), and obliteration of the greater saphenous vein using VNUS<sup>®</sup> and varicosectomy in 44 cases (3.1%). The total number of limbs treated for varicose veins were 1,407 cases (Table 3).

**Table 1.** Age/sex Distribution

Age	Male	Female	Total (cases/%)
< 29	49 (13.3)	39 (4.6)	88 (7.2)
30 - 39	65 (17.7)	187 (22.1)	252 (20.8)
40 - 49	100 (27.1)	324 (38.4)	424 (35.0)
50 - 59	97 (26.4)	226 (26.8)	323 (26.7)
> 60	57 (15.5)	67 (7.9)	124 (10.2)
Total	368 (30.3)	843 (69.7)	1,211 (100)

**Table 3.** Types of Operation

Types	Cases (%)
GSV HL, stripping and VS	958 (68.0)
SSV HL and VS	222 (15.8)
External banding valvuloplasty of GSV and VS	143 (10.2)
Linton's operation	21 (1.5)
VS only	19 (1.4)
VNUS <sup>®</sup> and VS	44 (3.1)
Total	1,407 (100)

GSV, Greater saphenous vein; SSV, Short saphenous vein; HL, High ligation; VS, Varicosectomy.

**Table 4.** Changes of Venous Hemodynamics in GSV Stripping and Varicosectomy

	Pre-op	Post-op	Reduction %	<i>p</i> -value
VV (ml)	142.1 ± 45.1	108.5 ± 32.4	20.9 ± 14.1	1.96E-18
VFI (ml/sec)	6.1 ± 3.1	1.7 ± 0.8	63.6 ± 20.7	1.77E-57
EF (%)	53.6 ± 11.3	64.2 ± 12.7	-25.0 ± 28.2	2.13E-20
AVP (mmHg)	41.9 ± 11.6	28.7 ± 11.6	25.4 ± 32.2	5.74E-32

GSV, Greater saphenous vein; VV, Venous volume; VFI, Venous filling index; EF, Ejection fraction; AVP, Ambulatory venous pressure.

**Table 5.** Changes of Venous Hemodynamics in External Banding Valvuloplasty of GSV and Varicosectomy

	Pre-op	Post-op	Reduction %	<i>p</i> -value
VV (ml)	98.1 ± 25.5	84.0 ± 21.3	12.0 ± 14.7	.001
VFI (ml/sec)	3.5 ± 1.7	1.4 ± 0.7	38.8 ± 40.9	3.79E-13
EF (%)	53.1 ± 11.2	60.6 ± 13.1	-21.0 ± 30.0	.0008
AVP (mmHg)	37.9 ± 11.5	30.4 ± 12.0	-6.1 ± 58.1	.0008

GSV, Greater saphenous vein; VV, Venous volume; VFI, Venous filling index; EF, Ejection fraction; AVP, Ambulatory venous pressure.

### Changes of venous hemodynamics

The high ligation and stripping of the greater saphenous vein, and varicosectomy (GSV stripping group) group showed a decrease in VV, VFI, AVP, and an increase in EF, and these widths of changes were statistically significant (Table 4). These changes were applied to the external banding valvuloplasty of the greater saphenous vein and varicosectomy group (GSV valvuloplasty

group), the high ligation of the short saphenous vein and varicosectomy group (SSV group), and the obliteration of the greater saphenous vein using VNUS<sup>®</sup> and varicosectomy group (VNUS group) (Tables 5, 6, 7, Fig. 1, 2, 3). The reduction rate of VV was 20.9 ± 14.1% in the GSV stripping group, 12.0 ± 14.7% in the GSV valvuloplasty group, 18.3 ± 16.1% in the VNUS group, and 20.6 ± 15.9% in the SSV group. The reduction rate of VFI was 63.6 ± 20.7% in the GSV stripping group,

**Table 6.** Changes of Venous Hemodynamics in VNUS<sup>®</sup> of GSV and Varicosectomy

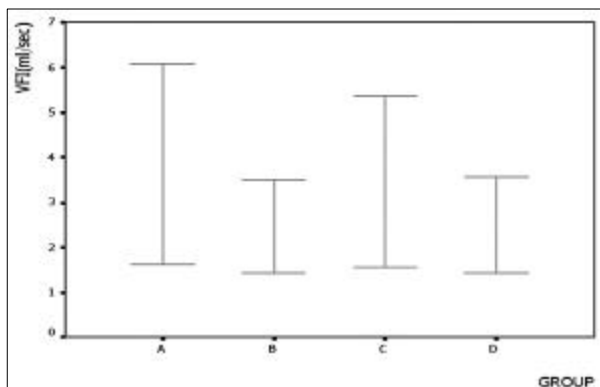
	Pre-op	Post-op	Reduction %	p-value
VV(ml)	114.7 ± 23.3	91.8 ± 21.9	18.3 ± 16.1	.0012
VFI(ml/sec)	5.4 ± 26.0	1.6 ± 0.6	60.1 ± 23.9	1.72E-08
EF(%)	55.9 ± 10.4	68.8 ± 11.6	-29.4 ± 31.9	.0002
AVP(mmHg)	40.2 ± 11.6	24.8 ± 11.7	28.4 ± 38.5	1.82E-05

GSV, Greater saphenous vein; VV, Venous volume; VFI, Venous filling index; EF, Ejection fraction; AVP, Ambulatory venous pressure.

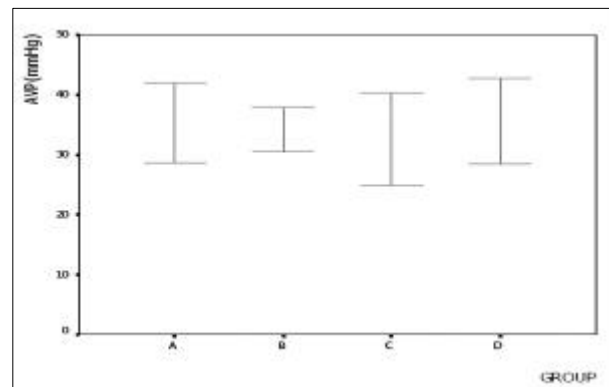
**Table 7.** Changes of Venous Hemodynamics in High Ligation of SSV and Varicosectomy

	Pre-op	Post-op	Reduction %	p-value
VV(ml)	128.7 ± 39.1	94.8 ± 23.5	20.6 ± 15.9	3.89E-06
VFI(ml/sec)	3.6 ± 2.5	1.4 ± 0.7	37.6 ± 30.2	.0001
EF(%)	52.9 ± 10.9	63.2 ± 12.2	-30.0 ± 36.5	8.74E-08
AVP(mmHg)	42.8 ± 11.8	28.5 ± 11.9	14.1 ± 49.0	5.89E-14

SSV, Short saphenous vein; VV, Venous volume; VFI, Venous filling index; EF, Ejection fraction; AVP, Ambulatory venous pressure.



**Fig. 1.** Venous filling index change in pre- and post-operative data between each of the 4 groups. Group A=Greater saphenous vein stripping; Group B=External banding valvuloplasty of Greater saphenous vein; Group C=VNUS<sup>®</sup>; Group D=Short saphenous vein stripping.



**Fig. 2.** Ambulatory venous pressure change in pre- and post-operative data between each of the 4 groups. Group A=Greater saphenous vein stripping; Group B=External banding valvuloplasty of Greater saphenous vein; Group C=VNUS<sup>®</sup>; Group D=Short saphenous vein stripping.

38.8 ± 40.9% in the GSV valvuloplasty group, 60.1 ± 23.9% in the VNUS group, and 37.6 ± 30.2% in the SSV group. The increasing rate of EF was 25.0 ± 28.2% in the GSV stripping group, 21.0 ± 30.0% in the GSV valvuloplasty group, 29.4 ± 31.9% in the VNUS group, and 30.0 ± 36.5% in the SSV group. The reduction rate of AVP was 25.4 ± 32.2% in the GSV stripping group, -6.1 ± 58.1% in the GSV valvuloplasty group, 28.4 ± 38.5% in the

VNUS group, and 14.1 ± 49.0% in the SSV group. These rates of changes in each of the 4 groups were not statistically significant (Table 8, Fig. 4 and 5).

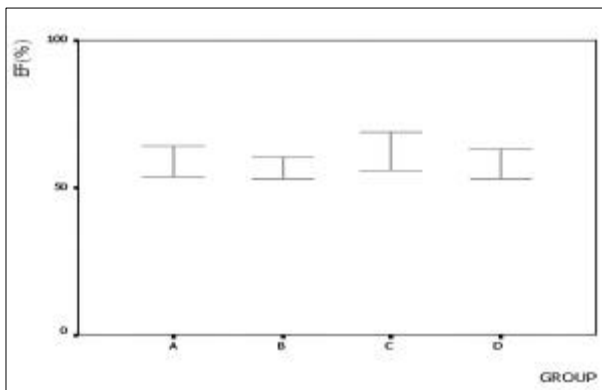
### Complications

Postoperative complications corresponded to a total of 41 cases (2.9%). There were 15 cases in the

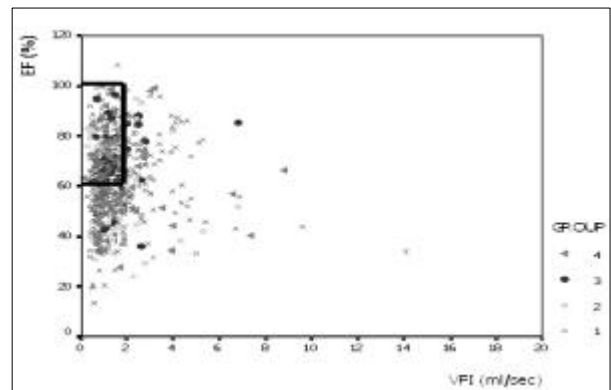
**Table 8.** Differences in the Reduction Rate (%) of Venous Hemodynamics

	GSV stripping	GSV valvuloplasty	VNUS <sup>®</sup>	SSV HL & VS	p-value
VV (ml)	20.9 ± 14.1	12.0 ± 14.7	18.3 ± 16.1	20.6 ± 15.9	.272
VFI (ml/sec)	63.6 ± 20.7	38.8 ± 40.9	60.1 ± 23.9	37.6 ± 30.2	.117
EF (%)	-25.0 ± 28.2	-21.0 ± 30.0	-29.4 ± 31.9	-30.0 ± 36.5	.681
AVP (mmHg)	25.4 ± 32.2	-6.1 ± 58.1	28.4 ± 38.5	14.1 ± 49.0	.449

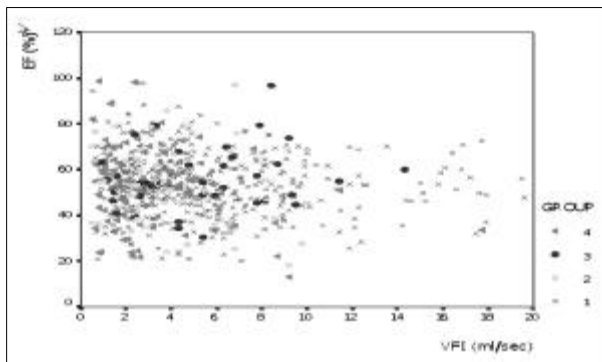
GSV, Greater saphenous vein; SSV, Short saphenous vein; HL, High ligation; VS, Varicosectomy; VV, Venous volume; VFI, Venous filling index; EF, Ejection fraction; AVP, Ambulatory venous pressure.



**Fig. 3.** Ejection fraction change in pre- and post-operative data between each of the 4 groups. Group A=Greater saphenous vein stripping; Group B=External banding valvuloplasty of Greater saphenous vein; Group C=VNUS<sup>®</sup>; Group D=Short saphenous vein stripping.



**Fig. 5.** The scatter plot graph in relation to the venous filling index and the ejection fraction; postoperative 1 month. Group 1=Greater saphenous vein stripping; Group 2=External banding valvuloplasty of Greater saphenous vein; Group 3=VNUS<sup>®</sup>; Group 4=Short saphenous vein stripping.



**Fig. 4.** The scatter plot graph in relation to the venous filling index and the ejection fraction; preoperative. Group 1=Greater saphenous vein stripping; Group 2=External banding valvuloplasty of Greater saphenous vein; Group 3=VNUS<sup>®</sup>; Group 4=Short saphenous vein stripping.

GSV stripping group, 1 case in the GSV valvuloplasty group, 24 cases in the VNUS group, and 1 case in the SSV group (Table 9).

## DISCUSSION

The primary varicose vein of the lower extremity was induced by incomplete valvular dysfunction of the saphenofemoral junction due to continuous, increased venous pressure of congenital or acquired weakening venous walls and valves. Such conditions raised the reflux of venous flow and in turn, caused the expansion of superficial veins. The varicose vein of the lower extremity can be divided into primary and secondary varicose veins by means of causes. Three factors dominate the theories on the etiology of primary varicose veins: valvular incompetence, weakness in the vein wall, and arteriovenous fistulae,<sup>1</sup> but no definite cause has yet been proved. On the other hand, the main etiology of the secondary varicose vein is the post-thrombotic

**Table 9.** Postoperative Complications in Each of the 4 Groups

Operation	Complications	Cases
GSV stripping	Ecchymosis	7
	Lymphorrhea	4
	Paresthesia	2
	Partial peroneal nerve injury	1
	Archilles tendinitis	1
GSV valvuloplasty	Hematoma	1
	Cord like mass	20
VNUS <sup>(®)</sup>	Paresthesia	2
	Deep vein thrombosis	1
	Tenderness	1
SSV HL & VS	Paresthesia	1
Total	41 (2.9%)	

GSV, Greater saphenous vein; SSV, Short saphenous vein; HL, High ligation; VS, Varicosectomy.

complication. According to the reports of Lofgren<sup>2</sup> and Myers,<sup>3</sup> the male-to-female ratio was 1 : 2, and varicose veins were most frequently found in patients in their forties. In our study, the male-to-female ratio was 1 : 2.3, and the mean age was  $46.9 \pm 10.3$  years of age. Etiologic factors varied, including hereditary cause, occupation requiring long hours of standing, pregnancy, trauma to the lower extremity, obesity, hormone imbalance, etc. Sisto<sup>4</sup> reported that age, height, occupations requiring long hours of standing, increased frequency of pregnancy were possible causes. The effect of hormones<sup>5</sup> and increased circulating venous flow during pregnancy have been considered as causes of female primary varicose veins, and from our experience, cases related to pregnancy corresponded to 403 cases which were approximately half the total female cases (48.8%). In our study, the duration from the first development of signs and symptoms to their primary treatment was 6 to 10 years in 388 cases (32.8%) and 11 to 20 years in 330 cases (27.9%). Jacobson<sup>6</sup> and Myers<sup>3</sup> reported that the mean durations were 9.3 years, and, 17.2 years, retrospectively. In other reports such as Kim's,<sup>7</sup> cases with a mean duration over 10 years ranked 35.5% and in Joh's report,<sup>8</sup> the mean duration was 12.5

years. Treatment modalities of varicose veins were divided into conservative, sclerotic, and operative methods. Conservative treatment is defined as the appliance of elastic bandage to the diseased extremity. Compressive sclerotic treatment is the appliance of elastic bandage for 6 weeks after the injection of a sclerosant. Hobbs<sup>9</sup> reported that operations was more effective over compressive sclerotic treatment in later results, even if the initial results of the compressive sclerotic treatment were better than the opposite. He asserted that from the basis of his results, operation was recommended for the greater and short saphenous veins. We performed 143 cases (10.2%) of external banding valvuloplasty using Dacron-tailored mesh (LARS( Mesh, Meadox Medicals Inc., USA). The detailed procedure of this valvuloplasty has been reported previously.<sup>10</sup> Allan<sup>11</sup> and Christopoulos<sup>12</sup> reported that VV ranged between 100-150ml in normal limbs and up to 350ml in limbs with venous disease. In addition, Christopoulos<sup>12,13</sup> reported that VFI was less than 2 ml/sec in normal limbs, and had increased up to 30 ml/sec in limbs with venous reflux. We evaluated the degree of venous reflux using VV and VFI. EF showed the ejection capacity of the calf muscle pump,<sup>14,15</sup> which was more than 60%

in normal limbs. RVF showed the overall performance of the calf muscle pump, and it correlated well with the measurements of AVP.<sup>14</sup> The total parameters of venous hemodynamics (i.e. VV, VFI, EF, RVF) showed statistically significant changes before and one month after the operation in our study; that is, increases in VV, VFI, AVP, and a decrease in EF. VFI had decreased to less than 2 ml/sec, and these results showed an improvement of venous reflux after each operation in the first postoperative month. AVP had decreased to less than 30 mmHg, and these results showed an improvement in the overall performance of the calf muscle pump after each operation in the first postoperative month. EF had increased to more than 60%, which showed an improvement in the ejection capacity of the calf muscle pump after each operation in the first postoperative month. Scatter plot graphs were created on the relationship of VFI and EF which were adapted in the Nicolaides's report,<sup>16</sup> and it was observed that venous hemodynamic changes of all four groups of our study illustrated improvement (within limits of EF 60-100% and VFI 0-2 ml/sec). Our results could be summarized as follows. First, APG showed an improvement in venous hemodynamics after operation as demonstrated by a decrease in VV, VFI, AVP and an increase in EF. Second, APG is an effective measurement to provide quantitative information on venous hemodynamics. Third, there was no difference in the reduction rate of venous hemodynamics between each of the 4 groups postoperatively. In conclusion, if we correct the incompetence of the saphenous vein and remove the varicosities, differences could not be found regardless of any operative modalities.

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