THE EFFECT OF SPLANCHNIC SYMPATHECTOMY IN HYPERTENSIVE PATIENTS UPON ESTIMATED HEPATIC BLOOD FLOW IN THE UPRIGHT AS CONTRASTED WITH THE HORIZONTAL POSITION [1]

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INTRODUCTION

It has been found that when normotensive or hypertensive subjects are tilted passively into an upright position estimated hepatic blood flow (EHBF) (2) decreases and calculated hepatic portal resistance (HPR) increases (3). These changes were assumed to be due to active splanchnic vasoconstriction, probably mediated over the splanchnic sympathetic nervous system. Direct evidence bearing on this assumption became available in some of the hypertensive patients undergoing splanchnic sympathectomy and subsequently studied by the same methods as before operation. Such studies are the basis of the present report.

METHOD

The method was identical with that used in the preoperative studies already reported (3). The first postoperative study was usually done within two weeks after the completion of the second stage of the splanchnicectomy, and, if possible, a second within 12 months. In addition, a few patients were studied one to nine years after (but not before) operation. The type of sympathectomy, unless otherwise noted in Table I, was the lumbodorsal (thoracolumbar) splanchnicectomy of Smithwick (4). After operation some patients [3] were unable to stand for any considerable length of time at a 75° tilt without marked postural hypotension and symptoms of faintness. Therefore, they were tilted back either to less marked angles (as noted in Table I) that they could tolerate long enough for reliable observations to be made, or to the horizontal position where paired samples of blood were drawn immediately for measurement of EHBF which, because of the time lag previously found to occur in this situation (3), was related to the upright period just before the tilt-back.

RESULTS

After lumbodorsal splanchnicectomy postural hypotension occurred to some extent in almost all the patients, particularly early after the operation. If it appeared suddenly it resulted not only in less accurate measurements of arterial pressure (which varied from moment to moment as the patient sighed or moved), but also in other technical difficulties, since it made it necessary hurriedly to terminate the period of upright posture, rather than leisurely to proceed until a more steady state of EHBF had been achieved. For these reasons the results in these instances were considered less reliable as equilibrium values than those observed when the patient was able to stand without great difficulty for a considerable period of time.[4]

In all cases after splanchnicectomy there were more nearly proportional decreases of EHBF and mean (one-half systolic plus diastolic) arterial pressure in the upright position (Table I) than before operation when relatively large reductions of hepatic blood flow and small changes of arterial pressure were usually found (Table II). Therefore, after operation calculated hepatic portal resistance (HPR) was often unchanged in the upright position whereas before operation it was usually increased. Thus, comparing average equilibrium figures, HPR in eight splanchnicectomized hypertensive patients increased on tilting from 6.8 to only 7.2, or 6% (which is not significant statistically), whereas in nine unoperated hy-

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[3] No patient was allowed to wear his abdominal pressure girdle or elastic stockings during the test.

[4] Only those data obtained after four minutes in a given position and without fainting are included in the statistical analysis in Table II.

TABLE I

Effects of the upright posture upon estimated hepatic blood flow (EHBF), mean (half systolic plus diastolic) arterial pressure, calculated hepatic portal resistance (HPR) and pulse rate in splanchnicectomized hypertensive patients, listed in order of the relative completeness of the sympathectomy, as judged by anatomic and physiologic criteria (4–6)

Patient Age Sex Surface area (*sq. m.*)	Time after operation	Horizontal position, Control period				Upright position						Horizontal position, Recovery period				
		EHBF (*cc./min./1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/cc./sec./1.73 sq. m.*)	Pulse rate (*Beats/min.*)	Minutes after tilt-up	Degree of tilt	EHBF (*cc./min./1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/cc./sec./1.73 sq. m.*)	Pulse rate (*Beats/min.*)	Minutes after tilt-back	EHBF (*cc./min./1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/cc./sec./1.73 sq. m.*)	Pulse rate (*Beats/min.*)
Sta		1,336	126	5.7	69	3	75°	878	79	5.4	74	4	969	114	7.1	69
44	2 weeks*	970	125	7.7	69	6	75°	780	75	5.8	72	12	995	124	7.5	66
M		—	—	—	—	13	55°	490	66	8.1	72	21	1,135	122	6.4	66
1.91												30	1,174	123	6.3	69
Gol		1,005	177	11.0	84	5	60°	726	143	12.0	90	6	1,246	178	8.6	84
31	9½ weeks	1,120	184	9.9	84	9	60°	875	149	10.0	84	11½	1,228	177	8.6	88
M		1,381	181	7.9	92	15	60°	977	147	9.0	90	—	—	—	—	—
1.81																
		1,214	159	7.9	70	7	50°	1,267	150	7.1	94	5½	1,956	172	5.3	87
	7 months	1,366	169	7.4	76	15	40°	1,200	151	7.6	90	11	1,888	167	5.3	82
		1,374	171	7.5	74	20½	40°	1,276	160	7.5	91	—	—	—	—	—
Pau		2,330	121	3.1	72	4	75°	1,792†	71	2.4	?	5½	1,260	127	6.0	72
36	2 weeks	—	—	—	—	—	—	—	—	—	—	11½	1,678	124	4.4	78
M		—	—	—	—	—	—	—	—	—	—	22½	1,774	127	4.3	72
1.84																
Max		1,168	107	5.5	60	4	75°	899	77	5.1	120	5	1,496	105	4.2	58
43	2 weeks	1,435	112	4.7	58	7	60°	475‡‖	71	9.0	?	11	1,547	109	4.2	65
M		—	—	—	—	—	—	—	—	—	—	20	1,300	116	5.4	58
2.21		—	—	—	—	—	—	—	—	—	—	30½	1,255	115	5.5	66
McC		3,510	158	2.7	90	3½	75°	1,455	131	5.4	120	4	1,816	162	5.3	96
43	2 weeks	2,273	166	4.4	96	7½	75°	2,434	133	3.3	114	11½	2,938	159	3.3	90
M		—	—	—	—	—	—	—	—	—	—	24	1,790	159	5.3	96
1.75		—	—	—	—	—	—	—	—	—	—	32	2,727	167	3.7	96
		1,623	177	6.5	68	3½	75°	1,126	150	8.0	96	5	2,339	164	4.2	64
		1,908	176	5.5	68	9	60°	974	142	8.8	80	14½	2,363	154	3.9	72
	6 months	1,512	179	7.1	68	14	45°	1,069	144	8.1	80	23	1,619	158	5.9	72
		—	—	—	—	20	45°	1,352	151	6.7	88	32	2,029	166	4.9	72
She		1,813	163	5.4	84	3	75°	2,860†	104	2.2	108	6½	1,535	182	7.1	84
51	2 weeks	—	—	—	—	—	—	—	—	—	—	11½	1,525	160	6.3	88
M		—	—	—	—	—	—	—	—	—	—	18	1,757	162	5.5	90
2.02																
		1,568	132	5.1	68	9	45°	1,072	121	6.8	84	10	1,411	122	5.2	72
		1,384	134	5.8	68	13	45°	831	126	9.1	100	—	—	—	—	—
	4 months	1,234	134	6.5	68	19	45°	939	117	7.5	88	—	—	—	—	—
						25	45°	1,062	109	6.2	84	—	—	—	—	—

TABLE I—*Continued*

Patient Age Sex Surface area (*sq. m.*)	Time after operation	Horizontal position, Control period				Upright position						Horizontal position, Recovery period				
		EHBF (*cc./min./ 1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/ cc./sec./ 1.73 sq. m.*)	Pulse rate (*Beats/min.*)	Minutes after tilt-up	Degree of tilt	EHBF (*cc./min./ 1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/ cc./sec./ 1.73 sq. m.*)	Pulse rate (*Beats/min.*)	Minutes after tilt-back	EHBF (*cc./min./ 1.73 sq. m.*)	Mean arterial pressure (*mm. Hg*)	HPR (*mm. Hg/ cc./sec./ 1.73 sq. m.*)	Pulse rate (*Beats/min.*)
Dea		1,867	159	5.1	81	4	75°	1,328	136	6.1	99	3	652‖	147	14.0	84
54	2 weeks	2,286	150	3.9	78	7	75°	2,418	138	3.4	102	9½	2,044	171	5.0	87
M		—	—	—	—	—	—	—	—	—	—	16½	2,615	156	3.6	84
1.82																
		1,477	176	7.1	66	7	75°	1,113	175	9.4	78	11	1,569	176	6.7	72
		1,545	175	6.8	69	11	75°	1,416	157	6.6	79	18	1,461	169	6.9	66
	7 months	1,399	185	7.9	72	16½	75°	1,270	164	7.7	83	23	1,275	182	8.6	72
		—	—	—	—	21½	75°	1,304	165	7.6	84	—	—	—	—	—
O'Le																
		1,289	126	5.9	81	3½	75°	745†	?	?	?	7	874	129	8.9	82
47	9 years	1,403	127	5.4	80	—	—	—	—	—	—	15½	1,004	120	7.2	75
F		—	—	—	—	—	—	—	—	—	—	21½	1,505	118	4.7	75
1.56																
Lee																
		779	106	8.2	60	20	75°	791	108	8.2	90	5½	839	116	8.3	60
35	4 years	891	105	7.1	52	25	75°	746	108	8.7	90	13	814	111	8.2	68
M		—	—	—	—	—	—	—	—	—	—	21	902	111	7.4	68
2.21																
Yof																
42	1 year	1,152	137	7.1	75	6	75°	1,184†	?	?	?	11	1,122	130	7.0	75
F		1,199	137	6.9	75	—	—	—	—	—	—	27	1,250	127	6.1	74
1.68																
Bar																
		943	143	9.1	60	4½	75°	780	124	9.5	104	5½	623	145	14.0	51
52	3 years	908	149	9.8	55	—	—	—	—	—	—	11½	736	141	12.0	69
F		834	154	11.0	71	—	—	—	—	—	—	20½	672	146	13.0	67
1.85																
Dun																
		2,378	108	2.7	84	3½	75°	690	88	7.7	155	4	884	130	8.8	86
30	2 weeks§	2,058	108	3.2	89	—	—	—	—	—	—	15½	1,218	98	4.8	92
M		1,687	111	4.0	93	—	—	—	—	—	—	—	—	—	—	—
1.82																

* Patient previously had had an incomplete splanchnicectomy elsewhere; present operation was a total thoracic extension (Rt = D1–D9; Lt = D1–D8) with bilateral excision of greater splanchnic nerves.

† Patient faint, tilted back, sample for EHBF taken immediately.

‡ Patient faint, sample for EHBF taken, tilted back immediately.

‖ This value was obtained during a rapid rise (greater than 0.0006 mg./cc./min.) in the peripheral venous serum concentration of BSP. It is questionable and is deleted from the statistical analysis (Table II).

§ Patient had a supradiaphragmatic splanchnicectomy (Rt = D7–D12; Lt = D8–D12, inclusive).

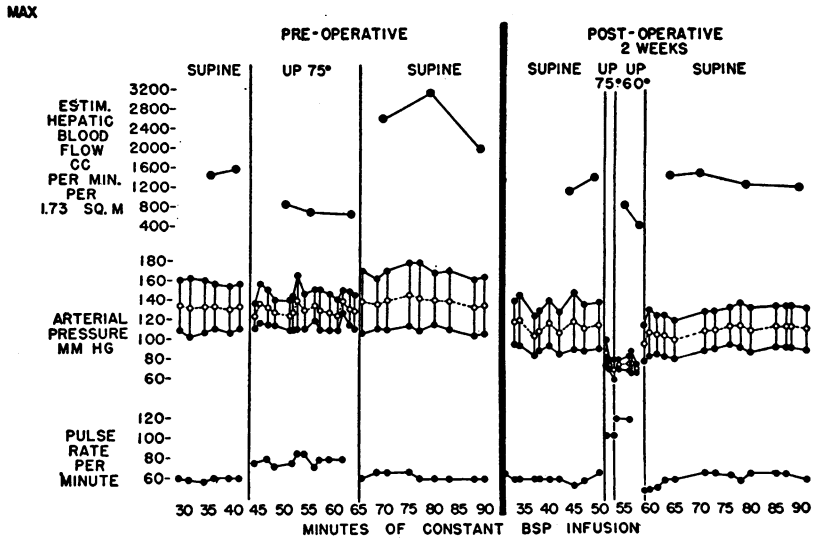

FIG. 1. CHART OF EHBF, ARTERIAL PRESSURE AND PULSE RATE OF A HYPERTENSIVE PATIENT (MAX), STUDIED IN THE HORIZONTAL AND UPRIGHT POSITIONS BEFORE AND AFTER A LUMBODORSAL SPLANCHNICECTOMY

"Mean" (half systolic plus diastolic) arterial pressure is indicated by the open circles and interrupted lines. During and after the upright position in the preoperative test, this patient had a marked anxiety reaction that began with a severe headache.

pertensive patients it increased from 7.3 to 10.1, or 38% (which is highly significant statistically).

The findings in the splanchnicectomized group may also be demonstrated by charts of experiments done on individual cases before and after operation (Figures 1, 2). Here the reductions of EHBF

TABLE II

The effect of splanchnicectomy on the mean responses of the estimated hepatic blood flow (EHBF), arterial pressure and hepatic portal resistance (HPR) to upright tilting of the body*

	EHBF (*cc./min./1.73 sq. m.*)			Mean§ arterial pressure (*mm. Hg*)			HPR (*mm. Hg/cc./sec./1.73 sq. m.*)		
	Horizontal (Control)	Upright	Horizontal (Recovery)	Horizontal (Control)	Upright	Horizontal (Recovery)	Horizontal (Control)	Upright	Horizontal (Recovery)
Splanchnicectomized patients (11 experiments on 8 patients)									
Mean	1,472	1,171	1,521	149	125	148	6.8	7.2	6.6
Standard Error of Mean	176	163	172	8	9	8	0.6	0.6	0.8
Mean Difference†	—	−301	+360	—	−24	+23	—	+0.4	−0.5
Significance of Difference (P)‡	—	**<0.01**	**<0.01**	—	**<0.01**	**<0.01**	—	0.09	0.44
Unoperated hypertensive patients (n = 9)									
Mean	1,357	960	1,417	158	157	155	7.3	10.1	7.2
Standard Error of Mean	97	68	172	7	7	8	0.6	0.7	0.7
Mean Difference†	—	−397	+428	—	−1	0	—	+2.8	−2.4
Significance of Difference‡	—	**<0.01**	**<0.05**	—	0.78	0.97	—	**<0.01**	**<0.01**

* The mean values of EHBF, arterial pressure and HPR for the group were calculated from the averages of the observations on each individual. See Table I for details of splanchnicectomized patients, and the preceding paper (3) for unoperated hypertensive patients.

† Differences refer to the changes from the immediately preceding position.

‡ The significance of the difference was calculated by the method of Fisher for unique samples (8). P values of 0.05 or less (bold type) denote "significant" differences, and values of 0.01 or less "highly significant" differences.

§ Average of systolic and diastolic pressures.

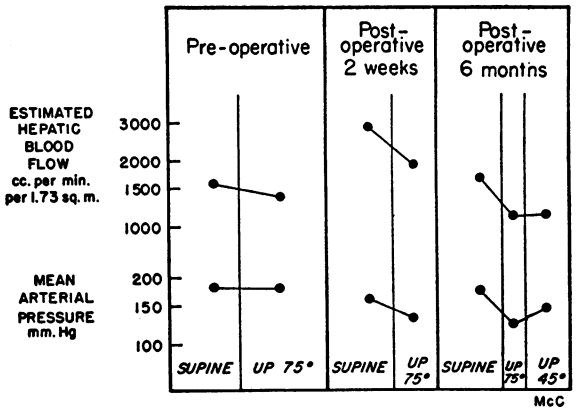

FIG. 2. CHART OF AVERAGE EHBF AND "MEAN" (HALF SYSTOLIC PLUS DIASTOLIC) ARTERIAL PRESSURE IN THE HORIZONTAL AND UPRIGHT POSITIONS IN A HYPERTENSIVE PATIENT (McC) BEFORE, TWO WEEKS AFTER, AND SIX MONTHS AFTER LUMBODORSAL SYMPATHECTOMY

in the upright position before operation are seen to be essentially unrelated to changes in arterial pressure, whereas after operation they were usually associated with sizeable decreases in arterial pressure.

After return to the horizontal position the EHBF in post-operative, as in preoperative, patients usually returned toward, to, or above the previous horizontal control values. Arterial pressure recovered from postural hypotension and calculated HPR did not change significantly (Table II).

DISCUSSION

The results reported here indicate that the splanchnic sympathetic nervous system of hypertensive patients probably mediates, at least in part, the vasoconstrictor response in the hepatic portal circulation to the upright posture. Thus, sizeable increases in HPR usually did not occur in the upright position after splanchnicectomy, whereas in the same subjects before operation and in normotensive control subjects (3) they did occur. Obviously this does not prove that the changes in EHBF found after splanchnicectomy were only passive and due solely to associated changes in arterial pressure. However, since the decreases in EHBF in the upright position were no greater after than before operation, whereas the reductions in arterial pressure were much greater, one may assume that there was relatively much less active vasoconstriction in the hepatic-portal region after than before operation. These results give direct confirmation to independent hemodynamic studies in this laboratory which have shown that reflex vasopressor responses to certain blood-pressure-lowering stimuli, including the upright posture, are greatly reduced after splanchnicectomy (5, 6).

Besides elucidating the influence of the sympathetic nervous system upon hepatic-portal blood flow, these studies indicate the importance of hydrostatic factors, particularly of orthostatic arterial hypotension, upon EHBF. Decreases in arterial pressure, if sizeable, were usually associated with sizeable reductions of EHBF in sympathectomized patients. On the other hand, when minor changes of arterial pressure such as those usually encountered in normotensive or unsympathectomized hypertensive patients in the upright position occurred in splanchnicectomized patients they were associated with little change in EHBF.

Although for the reasons just given, both the activity of splanchnic sympathetic nervous system and the level of the arterial pressure appear to be important factors in the normal regulation of EHBF, other influences also must be assumed to play a role. Thus, even in well-sympathectomized patients, major "spontaneous" changes in EHBF occurred, particularly during and after orthostasis, that could not be accounted for on the basis of the first two factors alone. For example, after standing upright and being returned to the horizontal position some postoperative patients (Gol, McC, and Dea) had large increases in horizontal EHBF which could not be explained by rises in arterial pressure.

The observations made in patients during orthostatic syncope are also of interest in this connection. As mentioned in a previous paper (3), the tendency to collapse in the upright position before operation seemed usually related directly to the absolute level to which hepatic-portal blood flow fell. Thus, when EHBF fell to 750 cc./min. and failed to recover, collapse was usually imminent even though the arterial pressure up to that point had been well-sustained. After splanchnicectomy, however, while patients in the upright position usually had a lower arterial pressure and a proportionate decrease in EHBF (at times below 750 cc./min.), the expected circulatory "decompensation" characteristic of vaso-vagal syncope did not always appear (notably in Sta). On the other

hand, three splanchnicectomized patients (Pau, She and Yof) fainted while EHBF remained good and calculated HPR actually decreased.

The results of these studies provide probably valid indications of the physiologic role of the intact splanchnic sympathetic nervous system, not only in hypertensive but perhaps also in normotensive individuals with respect to the regulation of hepatic-portal blood flow. Along with other observations in this laboratory, they suggest that the sympathetic nervous system normally plays a vasoconstrictor role in the hepatic-portal circulation. The vasoconstrictor and vasodilator influences in this circuit may be presumed usually to be balanced. Conceivably, if they became unbalanced through either overactivity or inhibition of one as compared with the other, blood flow and calculated hepatic-portal resistance would change. Thus, it is possible that the early decrease and late return of increased HPR in resting horizontal hypertensive patients after splanchnicectomy (7) is due to an early unopposed, though normal, vasodilator activity followed by a moderation of that activity or by a return of "intrinsic vasoconstrictor tone," or both. Furthermore, it is possible that the sizeable "spontaneous" variations in EHBF observed after splanchnicectomy may be due to greater or lesser amounts of the remaining "vasodilator activity."

SUMMARY AND CONCLUSIONS

After splanchnic sympathectomy, reductions of hepatic blood flow in hypertensive patients tilted into the upright position are associated with sizeable decreases in arterial pressure and little change in average hepatic-portal resistance, whereas before operation reductions in EHBF in the upright position occur with little change in pressure and increases in HPR. It is concluded that the splanchnic sympathetic nervous system mediates the hepatic-portal vasoconstrictor response to the upright posture in hypertensive patients and probably also in normal subjects.

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